Bulletin 110

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

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CONCENTRATION EXPERIMENTS WITH THE SILICEOUS RED HEMATITE OF THE BIRMINGHAM DISTRICT, ALABAMA

BY
JOSEPH T. SINGEWALD, JR.

WASHINGTON
GOVERNMENT PRINTING OFFICE
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INTRODUCTION.

The possible value of the red hematite iron ore of the southern Appalachian States, if some practicable method of concentrating it could be devised, has long been recognized. The ore is very low grade, and although in enormous quantities, particularly in the States of Alabama, Tennessee, and Georgia, is only at a few points rich enough to work, and even the best of it ranks among the lowest grade iron ores being mined in the United States. A cheap method of beneficiating this ore would make enormous quantities available and vastly increase the iron-ore resources of the country. However, this low-grade ore in effect constitutes a potential iron reserve, and as long as ample quantities of ore can be obtained elsewhere the question of its utilization does not demand immediate notice.

Where these ores are in part of workable grade, however, a problem of more immediate importance arises which, from considerations of economy and prevention of waste in their mining, ought to be solved or, at least, attacked as quickly as possible. Where these ores are being worked they are usually intimately associated with lower-grade material that in mining is left behind. The difficulty and expense of going into ground broken by old workings makes the recovery of this lower-grade ore practically impossible and it is lost forever. Success in concentrating the red ores, therefore, would save material that is now being irretrievably lost. The successful large-scale concentration of low-grade ore in the last few years on the Lake Superior iron ranges should encourage the attack of similar problems in the Birmingham district.

While studying iron-mining methods in the United States for the Bureau of Mines, Dwight E. Woodbridge, consulting mining engineer of the bureau, was impressed with the importance of this problem, and believed it merited the attention of the bureau. Accordingly, Mr. Woodbridge had Mr. W. J. Penhallegon, general superintendent of ore mines and quarries of the Republic Iron & Steel Co., of Birmingham, send the author of this report five samples

of the unworkable siliceous ores of the district. The results of concentration experiments with these ores made a more thorough and systematic investigation desirable. In consequence, the author subsequently collected samples in the district, and these became the basis of the experimental work described in this report. The results are published by the Bureau of Mines as a part of its efforts to increase efficiency in the utilization of mineral resources.

The experiments were conducted in the geological laboratory of the Johns Hopkins University, Baltimore, Md., with the aid of Raymond Leibensperger, mining assistant. The chemical analyses were made by A. C. Fieldner, chemist, of the Bureau of Mines.

The author wishes to express his appreciation of the courtesies extended to him by the mining companies of the district, and particularly to Mr. W. J. Penhallegon, of the Republic Iron & Steel Co. Thanks are also due Prof. W. B. Clark, director of the geological laboratory of the Johns Hopkins University, for the unrestricted use of the facilities of the laboratory.

GENERAL FIELD RELATIONS AND QUALITY OF THE ORES.

The general field relations of the ores of the Birmingham district have been fully described by Burchard and Butts,[a] and somewhat the same ground, with greater emphasis on the industrial conditions of the district, is covered by Phillips.[b] For detailed particulars on these points the reader is referred to these two reports, as no attempt will be made here to duplicate the information they present. For the benefit of those not especially interested in these points, and to make the purpose of this report more intelligible to such to whom the above publications are not available, a summary of the general field relations of the district is given.

EXTENT OF THE DISTRICT.

The Birmingham district is a narrow belt about 75 miles long and 10 miles wide, with a northeast trend. Near the middle of the belt is the city of Birmingham, which stands in a broad anticlinal valley, known as Birmingham Valley, that extends the whole length of the belt. The iron ores lie in the ridges on both sides of the valley, but by far the most important beds are along the east side, in what is known as Red Mountain. Nearly all of the mining in the district has been confined to that part of Red Mountain lying between Morrow Gap on the northeast and Sparks Gap on the southwest, a dis-

[a] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Ala., with chapters on the origin of the ores, by E. C. Eckel: Bull. 400, U. S. Geol. Survey, 1910, 204 pp.

[b] Phillips, W. B., Iron making in Alabama: 3d ed., Geol. Survey of Alabama, 1912, 254 pp.

tance of about 25 miles. This part of the district and the location of the mines from which the samples were collected are shown in Plate I. The area of greatest activity is even smaller, and in the summer of 1914, when the iron industry was at a low ebb, mining was practically confined to that part of Red Mountain between Graces Gap and Sparks Gap, a distance of about 10 miles. All the largest mines of the district are included in this latter area.

THE ORE BEDS.

The ores are bedded in the Clinton or Rockwood formation, of Silurian age, which outcrops along Red Mountain, and gives the mountain its name. The beds dip away from the valley at angles ranging from 15° to 45°, but averaging less than 30°. One or more ore beds of greater or less importance are everywhere present in the Rockwood formation, and within that part of Red Mountain of greatest economic importance—that is, between Morrow Gap and Sparks Gap—there are four important beds, known, respectively, in their order from top to bottom, as the Hickory Nut, Ida, Big, and Irondale seams. The Hickory Nut seam is the least important of the four and has received little attention. It comprises 3 to 5 feet of sandy ore or ferruginous sandstone, characterized by abundant fossils of the brachiopod *Pentamerus oblongus*, which, on account of looking like a hickory nut in its hull, has given the bed the name. The bed lies about 12 to 20 feet above the Ida seam and reaches its greatest thickness between Birmingham and Bessemer. The other three seams are described on subsequent pages in connection with the results of the concentration experiments.

MINERALOGICAL COMPOSITION OF THE ORES.

Mineralogically the ores consist of red hematite and include two structural varieties, oölitic and fossil, which usually occur mixed. Usually the nuclei of the oölites are small grains of sand, about which successive layers of iron oxide, and frequently thin layers of silica and aluminous material, have been deposited. The fossil ore consists of fragments of such fossil forms as bryozoans, crinoids, corals, and brachiopods.

In addition to the iron oxide the ores carry varying percentages of calcium carbonate, silica, alumina, magnesium carbonate, and other constituents in minor amounts. Where surface waters have leached out the calcium carbonate the ore is porous and friable, and is known as "soft ore"; in contrast, the unaltered ore is called "hard ore." The "hard ores" naturally form the great bulk of the deposits, and those mined at present range in composition from 32 to 45 per cent iron, 5 to 20 per cent lime, 2 to 25 per cent silica, 2 to 5 per cent

alumina, 1 to 3 per cent magnesia, 0.25 to 1.5 per cent phosphorus, from a trace up to 0.5 per cent sulphur, and 0.5 to 3 per cent water.[a] Actually the ores average well under 40 per cent iron, and their value depends chiefly on the relative proportions of lime and silica. Roughly speaking, a self-fluxing ore is one in which the lime is slightly in excess of the silica. As such an ore requires in smelting no addition of limestone, it is equivalent to a higher grade siliceous ore that requires added flux. If the proportion of lime is in excess of that required for a self-fluxing ore, a quantity of siliceous ore can be added. This is done in the district for the most part by using a mixed charge of limy ore and brown ore.

THE PROBLEM OF CONCENTRATION.

The great bulk of the red ore of the district is high in silica and comparatively low in lime, so that the addition of considerable flux would be necessary in smelting. The iron content of the ore is so low, however, that the iron content of the furnace charge would be reduced enough to make the use of the ores unfeasible. Only those ores, therefore, that are self-fluxing or nearly self-fluxing can be used at present.

How far the ore can depart from the self-fluxing type and still be workable depends entirely on the status of the iron industry. For example, the upper bench of the Big seam at the Spaulding mine is workable when the demand for iron is good and unworkable when the demand slumps. The average composition of this ore is about 35 to 36 per cent iron, 17 to 18 per cent silica, and 12 per cent lime, and it may be regarded as representing the dividing line between ore that is workable and ore that is not workable under average conditions.

Most of the ore of this composition, or better, lies between Birmingham and Bessemer, and is Big seam ore. But, as is explained more fully in the section dealing with the Big seam ores, only the upper part of the Big seam comes within these limits, consequently the lower part is left in the mines. As the old workings cave, the collapsed roof will make unprofitable the future mining of the rest of the bed. It is with reference to the lower bench of the Big seam in this part of the Birmingham district that this investigation is of most importance. For each ton of ore removed in mining at least one ton of the siliceous lower bench is left in the ground, and as the annual production is three to four million tons, the annual loss is at least that much. The total of the ore reserves in the lower bench

[a] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Alabama, with chapters on the origin of ores, by E. C. Eckels: U. S. Geol. Survey Bull. 400, 1910, p. 27.

of the Big seam within the area under consideration is estimated at 146,000,000 tons.[a]

An early solution of the problem of beneficiating these lower bench ores is, therefore, to be sought in order to stop the waste of resources that at some future time will undoubtedly have value. Also, the solution of this problem would place among the available iron-ore reserves of the country a vast tonnage of low-grade ores in other parts of Alabama, as well as in Tennessee and Georgia, and wherever the Clinton ores occur.

For the purpose of determining the possibility of removing silica and concentrating iron in these ores, 39 samples were taken from various mines lying along Red Mountain between the Ruffner mine on the northeast and the Fossil mines on the southwest; 2 of these samples were from the Ida seam, 3 from the Irondale, 24 represented the lower bench of the Big seam, and the other 10 were from the upper bench; 23 of the 24 lower bench samples were taken along Red Mountain southwest of Graces Gap; that is, in the mines where this ore is being lost.

EARLIER WORK ON THE BENEFICIATION OF THE CLINTON ORES.

The problem of beneficiating the Clinton ores has been attractive enough to stimulate numerous attacks in the past. Efforts have been directed toward applying some known method of treatment or toward devising some new method especially adapted to these ores. The fact that none of the methods is in use shows that the attempts were not commercially successful. Results of many experiments by private individuals on their own initiative or by private companies have never been made known. Recently an experimental mill, said to have a capacity of about 300 tons in 24 hours, was erected at one of the mines and has made trial runs, but the persons interested refuse to give out any data on the results.

The most extensive series of experiments that have been carried out seem to be those of Phillips,[b] and of Wilkens and Nitze,[c] made nearly 20 years ago.

Results are summarized in Phillips' Iron Making in Alabama, chapter IV, concentration of ores. In the first of these experiments the ore was heated to make it magnetic, and then passed over a

[a] Burchard, E. F., and Butts, Charles. Iron ores, fuels, and fluxes of the Birmingham district, Alabama, with chapters on the origin of the ores, by E. C. Eckel: U. S. Geol. Survey Bull. 400, 1910, p. 132.

[b] Phillips, W. B., Notes on the magnetization and concentration of iron ores: Trans. Am. Inst. Min. Eng., vol. 25, 1896, pp. 399–423; Concentration of low-grade iron ores: Eng. and Min. Jour., vol. 62, 1896, pp. 75, 76. 105, 106, 124, 125, 151.

[c] Wilkens, H. A. J., and Nitze, H. B. C., The magnetic separation of nonmagnetic material: Trans. Am. Inst. Min. Eng., vol. 26, 1897, pp. 351–370. Discussion of this paper by W. B. Phillips, pp. 1089–1093.

magnetic separator; but the experimenter soon found that magnetic separation could be effected directly. Numerous experiments were made on a working scale and about 500 analyses.

Attention was directed chiefly to the low-grade soft ores, and the experiments demonstrated that by crushing such ores to pass a 15-mesh screen, it was entirely feasible, with a ratio of concentration of 2 to 1 and an iron recovery of about 85 per cent, to make concentrates carrying over 50 per cent iron from ores that in their crude state were worthless. The average composition of eight samples of the low-grade crude tested was 38 per cent iron and 42.5 per cent silica. The average composition of the concentrates obtained was 52.34 per cent iron and 21.63 per cent silica, with a ratio of concentration of 1.93 and an average iron recovery of 71.4 per cent. This average concentrate is of somewhat higher grade than the average soft ore now mined. Phillips estimates the cost of producing a ton of 50 per cent iron concentrates under favorable conditions at about $1.35; he says that this kind of ore is worth $1.60 to $1.80 per ton, and that the price for 55 per cent concentrates would be $2 per ton.

The results of four tests of samples of hard ore, as given by Phillips, are as follows:

Results of 4 concentration tests of samples of hard ore.

Sample.	Crude ore.			Concentrates.			Ratio of concentration.	Iron recovery.
	Iron.	Lime.	Insoluble.	Iron.	Lime.	Insoluble.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*
A	37.60	15.00	16.20	48.70	9.76	10.26	1.82	71.2
B	34.50	17.10	18.04	45.40	11.45	12.25	1.56	84.2
C	31.80	10.79	33.10	43.15	8.80	19.66	2.27	59.7
D	32.80	9.90	33.70	44.50	9.00	17.30	1.73	78.7
Average	34.18	13.20	25.26	45.44	9.75	14.87	1.85	73.5

The first two of these samples represent an almost self-fluxing ore similar to those of the upper bench of the Big seam ores, and although beneficiation has yielded a much higher grade product, ores of this composition can be profitably smelted crude when the demand for iron is strong. Such ores are of slightly higher grade than the upper bench ores of the Spaulding mine, which are just about at the lower workable limit. The last two samples represent ores that more nearly approach the composition of the Ruffner ores described in this report and were decidedly low grade. The results Phillips obtained with these samples were not encouraging, and in this respect are like those the author obtained with the Ruffner ores. Although the concentrate was better than the crude ore, it was not of high enough grade to warrant the cost of treatment.

As the samples tested by Phillips represent two groups of ores of entirely different types, the average of the four samples has no particular significance. It is noteworthy that beneficiation did not reduce the lime content as much as the silica content, so that the concentrates are more nearly self-fluxing than is the crude ore. This result is in accordance with those obtained by the author of this report.

Another point on which the two series of experiments—by Phillips and the author—agree is that the iron content of the concentrates obtained from the soft ores is higher than 50 per cent, whereas that obtained from the hard ores runs below 50 per cent and is usually about 45 per cent.

Unfortunately these experiments throw little light on the amenability to treatment of the siliceous hematites having the composition of those in the lower bench of the Big seam. The upper bench self-fluxing ores are now being worked, and the concentration of the lower bench ores is of immediate importance.

Of great interest, because of the method used being essentially that used in this investigation, are some experiments made in a private laboratory at Wilmington, Del., with what is known as the Moxham-du Pont haloid process. The general results of these experiments have been cited by Burchard [a] and are given here in more detail with the consent of A. J. Moxham. The ore tested was from Pleasant Hill, Ala., and was too low grade for profitable mining. It was ground to pass through a 100-mesh screen and subjected to float and sink tests in troughs containing haloid solutions of specific gravity high enough to float the tailings. Three tests of this ore in solutions of different specific gravity gave the results shown below.

Results of 3 concentration tests.

No. of test.	Composition of—						Separation.		Ratio of concentration.	Iron recovered.	Specific gravity of solution.
	Crude ore.		Concentrates.		Tailings.		Concentrates.	Tailings.			
	Iron.	Insoluble.	Iron.	Insoluble.	Iron.	Insoluble.					
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*		*P. ct.*	
A	34.32	44.80	53.32	16.90	17.55	72.90	48.8	51.2	2.05	75.7	3.64
B	34.32	44.80	42.40	36.28	14.30	78.60	70.8	29.2	1.41	87.4	3.34
C	34.32	44.80	41.10	34.50	6.20	90.76	81.2	18.8	1.23	97.2	3.06

From its composition, this ore probably was a low-grade soft ore, and hence the results can not be compared with those of tests of the

[a] Burchard, E. F., in Contributions to economic geology. Preliminary report on the red iron ores of east Tennessee, northeast Alabama, and northwest Georgia: U. S. Geol. Survey Bull. 540, 1914, pp. 325–326; Geol. Survey of Tenn., Bull. 16, 1913, p. 161.

siliceous hard ores. The grade of the first concentrate is better than that of the best soft ores, so that the experiments show the possibility of making an easily marketable concentrate from an ore as siliceous as that used and of saving three-fourths of the iron in the crude ore. The cost of crushing to 100 mesh would probably be prohibitive in commercial work. Beneficiation of other low-grade iron ores by this method is being studied, and an experimental plant of commercial size has been erected for testing the Oriskony limonites at the Rich Patch mines in Virginia. If the method finally proves commercially practicable, it will be of great importance in the treatment of siliceous red hematites.

Ordinary wet methods of concentration are being used for treating low-grade iron ores on the Lake Superior ranges, and have proved so successful that the tonnage treated is continually increasing. However, these Lake Superior ores differ from the siliceous red hematites under consideration, and hence the results obtained can not be applied to the treatment of Clinton ores. Yet the work has shown that the concentration of iron ores by wet methods is feasible on a large scale.

METHOD OF CONDUCTING THE EXPERIMENTS.

About a pound of each sample was broken in a small Blake crusher and then crushed in a mortar until it all passed through a 20-mesh screen. A small quantity of the crushed ore was taken as a crude ore sample and the rest was subjected to a screen analysis. For this analysis the Tyler standard screen scale sieves were used, the sizes ranging from 20 mesh to 200 mesh. In these screens the openings are so arranged that they increase in the ratio of the square root of 2, the sizes in the screens used are given in the following table:

Mesh dimension of screens.

Mesh.	Opening in—	
	Inches.	Millimeters.
20	0.0328	0.833
28	.0232	.589
35	.0164	.417
48	.0116	.295
65	.0082	.208
100	.0058	.147
150	.0041	.104
200	.0029	.074

As all the sample was finer than 20 mesh, there were eight sizes of material. The seven coarsest were subjected to concentration, but what was finer than 200 mesh was regarded as slimes and was not treated.

To separate the heavier particles, high in iron, from the lighter particles, low in iron and high in silica, a heavy solution, Thoulet solution of a specific gravity of 3.0, was used. Each size of material was treated separately. It was mixed with some of the liquid in a separating funnel; the heavy particles settled to the bottom and the light particles floated, the two portions being then drawn off separately. In this way each sample yielded seven sizes of concentrates and of tailings, besides the slime.

METHOD OF PLOTTING RESULTS.

A graphic representation of the results was prepared by plotting the screen analysis as a broken curve, the sizes being used as abscissas and the percentages of the crushed ore as ordinates. The percentages of concentrates and tailings that each size yielded were also shown graphically. A second curve was plotted with the actual quantity of concentrate produced from each mesh size (percentage of concentrate of each size×percentage of total ore) as ordinates. This second curve clearly shows how much each mesh size contributes to the total concentrates. As the sum of these products gives the total percentage of concentrates from the sample, and as the slimes are known, the percentage of tailings is obtained by subtracting their sum (concentrates+slimes) from 100. These three percentages are represented by column A (see figs. 1–47) the lower part representing the concentrates, the middle lined part, the slimes, and the upper black part, the tailings. Column B in the figures is likewise divided into three corresponding parts, which show the percentage of the total iron in each. From these figures the ratio of concentration can be calculated for the concentrates alone, or of the product obtained by mixing the slimes and concentrates and considering it as the final product of the treatment.

From all but six samples the concentrates were mixed to form a sample of total concentrates, the tailings were mixed to form a total tailings sample, and these two products were analyzed for iron and silica. Also the crude ore sample and the slimes were analyzed. From these analyses and the percentages of concentrates, tailings, and slimes, the percentage of iron recovered in the concentrates can be calculated and also that of the concentrates plus slimes. As the slimes were of about the same composition as the concentrates, adding them to the concentrates much increased the apparent recovery.

In order to show how iron and silica are distributed in the different mesh sizes, and in the concentrates and tailings obtained from them, the concentrates and tailings from each mesh size of six samples were analyzed separately; and the composition of the crude ore of that mesh size, as well as the composition of the total concentrates

and tailings, were calculated from the analyses. Lime was determined often enough to show the relation of the lime in the crude ore to that in the concentrates. The pages that follow present the detailed results of these experiments.

RESULTS OF CONCENTRATION TESTS.

THE BIG SEAM.

The Big seam, as its name implies, is the important ore bed of the district, and in June, 1914, was the only one being worked. Its general characteristics are described by Burchard,[a] as follows:

> The thickness of the Big seam varies from 16 to 30 feet. It extends as a traceable unit on Red Mountain for practically the whole length of the mining district. Notwithstanding the great thickness there are rarely more than 10 to 12 feet of good ore in a single bench, and at most places only 7 to 10 feet are mined. Probably the maximum thickness of the bed, without reference to the thickness of the workable part, occurs between Red Gap (near Irondale) and Bald Eagle, although for a mile southwest of Red Gap the bed remains nearly as thick. From northeast to southwest the total thickness of the ore-bearing sediments gradually decreases, without, however, altering greatly the thickness of the workable portion. About the middle of the district the bed becomes separated into two benches, either by a well-defined parting along the bedding plane, or by a shale bed, thin at first, but thickening gradually to the southwest. The middle of the Big seam is the workable part in the northeast end of the district, but the upper bench is of most importance throughout the rest of the area. In the southwest portion of the district the lower bench, which farther northeast is composed of ore that may eventually be mined, becomes a series of strata of lean ore and shale and is consequently of no possible value; and finally the upper bench itself becomes shaly and carries only a very low-grade ore.

From this description of the Big seam it is evident that mining is removing 50 per cent or less of the ore, and the rest is being left in the ground, where the caving of the workings will make future recovery costly if not impossible. In the part of the district now most productive—that is, along Red Mountain from about south of Birmingham to Bessemer—the siliceous ores form the lower part of the seam and the less siliceous and more highly calcareous ores the upper part. Burchard says that in the northeast part of this strip the two benches are separated by a mere parting along the bedding and in many places there is no parting, the dividing line being purely arbitrary; whereas toward the southwest a thin shale parting that gradually increases in thickness comes in. In this part of the district, then, the upper part of the Big seam is being worked and the lower part left in the ground. Consequently most attention was paid to the lower bench ores of this area. However, several samples of upper bench ores were also tested for com-

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[a] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Alabama, with chapters on the origin of the ores, by E. C. Eckel: U. S. Geol. Survey Bull. 400, 1910, pp. 46, 47.

parison. On the following pages the tests of upper bench ores are considered apart from those of lower bench ores. Several tests were made of ores not included in either of these groups.

UPPER BENCH, BIG SEAM.

The character of the upper bench ore gradually changes north of a point about opposite Bessemer. Around Bessemer the ore contains a little more lime than is needed to flux the silica and alumina, and to such ore a siliceous ore can be added to make a self-fluxing charge. Northeastward the silica content rises and the lime content declines, until near Birmingham the ore becomes decidedly siliceous.

Phillips[a] says that hard red ore of good grade has the following composition:

Average composition of good hard ore.

	Per cent.
Water	0.50
Metallic iron	37.00
Silica	13.44
Lime	16.20
Alumina	3.18
Phosphorus	.37
Sulphur	.07
Carbonic acid	12.24

The term self-fluxing, so he states, is applied to those varieties of the limy ore in which the lime content equals the sum of the silica and alumina contents. Hence the analysis above represents a good self-fluxing ore. As the alumina content is usually small, a few per cent, a self-fluxing ore may roughly be considered one in which the lime content is a few per cent in excess of the silica content.

The ore from the mines about Readers Gap averages about 34 to 36 per cent Fe, 10 to 13 per cent SiO_2, about 18 per cent CaO, and nearly 4 per cent Al_2O_3; hence its lime content is higher than that required in a self-fluxing ore. Near Spring Gap the lime content is such that the ores are just about self-fluxing, and at Graces Gap the ores have a considerable excess of silica. Thus the ore of the Songo mine, just south of Spring Gap, averages about 34 per cent Fe, 12.5 per cent SiO_2, and 16 per cent CaO; whereas that from the Spaulding mine, at Graces Gap, averages about 36 per cent Fe, 19 per cent SiO_2, 13 per cent CaO, and nearly 3 per cent Al_2O_3. Northeast of Birmingham the ore grows still more siliceous and at the Ruffner mines averages about 32 per cent Fe, 31 per cent SiO_2, 9 per cent CaO, and 3 per cent Al_2O_3. Thus elimination of silica from upper bench Big seam ore is of importance except in the southwestern part of the district.

[a] Phillips, W. B., Iron making in Alabama, 3d ed.: Geol. Survey of Alabama, 1912, p. 35.

TABULATED RESULTS.

The results of the concentration tests of the 39 samples of ore collected from various mines are shown in the tables following:

TABLE 1.—*Results of crushing and separating samples from various mines.*

SAMPLE 1. ISHKOODA MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	66.3	21.8	64.5	35.5	14.1
28, on 35	74.2	24.5	68.1	31.9	16.7
35, on 48	54.1	17.8	66.0	34.0	11.7
48, on 65	26.2	8.6	57.1	42.9	4.9
65, on 100	24.8	8.2	53.6	46.4	4.4
100, on 150	18.3	6.0	57.7	42.3	3.5
150, on 200	10.5	3.5	60.9	39.1	2.1
200	29.2	a 9.6	....	....	0.0
	303.6	100.0	....	....	57.4

Total concentrates	per cent	57.4
Slimes	do	9.6
Tailings	do	33.0
		100.0

SAMPLE 2. SPAULDING MINE.

Through 20, on 28	129.5	28.2	68.9	31.1	19.4
28, on 35	105.8	22.8	73.4	26.6	16.7
35, on 48	76.3	16.5	75.2	24.8	12.4
48, on 65	41.7	9.0	75.0	25.0	6.8
65, on 100	33.8	7.3	73.4	26.6	5.4
100, on 150	26.0	5.6	75.5	24.5	4.2
150, on 200	17.6	3.8	89.9	10.1	3.4
200	31.6	a 6.8	....	....	0.0
	462.3	100.0	....	....	68.3

Total concentrates	per cent	68.3
Slimes	do	6.8
Tailings	do	24.9
		100.0

SAMPLE 3. SPAULDING MINE.

Through 20, on 28	119.4	25.6	68.9	31.1	17.6
28, on 35	103.9	22.3	73.1	26.9	16.3
35, on 48	75.7	16.2	75.2	24.8	12.2
48, 65	36.6	7.8	69.6	30.4	5.4
65, on 100	36.7	7.9	70.4	29.6	5.6
100, on 150	32.9	7.0	70.6	29.4	4.9
150, on 200	18.9	4.0	72.2	27.8	2.9
200	43.1	a 9.2	....	....	0.0
	467.2	100.0	....	....	64.9

Total concentrates	per cent	64.9
Slimes	do	9.2
Tailings	do	25.9
		100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 4. HAMMOND MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	107.2	28.3	47.1	52.9	13.3
28, on 35	83.1	22.0	53.9	46.1	11.9
35, on 48	54.2	14.3	60.9	39.1	8.7
48, on 65	28.4	7.5	71.6	28.4	5.4
65, on 100	30.2	8.0	77.4	22.6	6.2
100, on 150	25.8	6.8	78.2	21.8	5.3
150, on 200	15.4	4.1	79.0	21.0	3.2
200	34.2	[a] 9.0			0.0
	378.5	100.0			54.0

Total concentrates	per cent	54.0
Slimes	do	9.0
Tailings	do	37.0
		100.0

SAMPLE 5. RUFFNER MINE.

Size of mesh	Grams	Per cent	Concentrates	Tailings	Concentrates
Through 20, on 28	52.8	12.5	55.3	44.7	6.9
28, on 35	56.0	13.3	55.7	44.3	7.4
35, on 48	66.4	15.8	50.7	49.3	8.0
48, on 65	63.3	15.0	53.7	46.3	8.1
65, on 100	78.9	18.8	53.4	46.6	10.0
100, on 150	37.1	8.8	67.9	32.1	6.0
150, on 200	19.2	4.5	63.4	36.6	2.9
200	47.8	[a] 11.3			0.0
	421.5	100.0			49.3

Total concentrates	per cent	49.3
Slimes	do	11.3
Tailings	do	39.4
		100.0

SAMPLE 5. RUFFNER MINE (UNDER 35 MESH).

Size of mesh	Grams	Per cent	Concentrates	Tailings	Concentrates
Through 35, on 48	39.7	19.5	47.7	52.3	9.3
48, on 65	37.0	18.2	52.5	47.5	9.6
65, on 100	47.5	23.4	50.9	49.1	11.7
100, on 150	23.2	11.4	58.3	41.7	6.7
150, on 200	21.2	10.5	62.5	37.5	6.6
200	34.6	[a] 17.0			0.0
	203.2	100.0			43.9

Total concentrates	per cent	43.9
Slimes	do	17.0
Tailings	do	39.1
		100.0

[a] Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 6. RUFFNER MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	55.7	13.6	82.3	17.7	11.2
28, on 35	53.2	13.0	72.7	27.3	9.5
35, on 48	61.2	15.0	70.5	29.5	10.6
48, on 65	59.8	14.6	64.1	35.9	9.4
65, on 100	78.9	19.3	56.8	43.2	11.0
100, on 150	36.2	8.8	64.3	35.7	5.7
150, on 200	19.5	4.8	74.6	25.4	3.6
200	14.7	a 10.9			0.0
	409.2	100.0			61.0

Total concentrates .... per cent .. 61.0
Slimes .... do 10.9
Tailings .... do 28.1
100.0

SAMPLE 6. RUFFNER MINE (UNDER 35-MESH).

Through 35, on 48	46.7	18.5	49.3	50.7	9.1
48, on 65	42.8	17.0	48.0	52.0	8.2
65, on 100	65.1	25.8	47.2	52.8	12.2
100, on 150	30.9	11.9	55.5	44.5	6.6
150, on 200	17.1	7.0	69.5	30.5	4.9
200	50.0	a 19.8			0.0
	252.6	100.0			41.0

Total concentrates .... per cent .. 41.0
Slimes .... do 19.8
Tailings .... do 39.2
100.0

SAMPLE 7. FRANK WHITE MINE.

Through 20, on 28	112.2	26.7	65.7	34.3	17.5
28, on 35	91.7	21.8	73.4	26.6	16.0
35, on 48	57.7	13.7	75.7	24.3	10.4
48, on 65	33.3	7.9	86.1	13.9	6.8
65, on 100	35.4	8.4	86.4	13.6	7.3
100, on 150	32.2	7.7	90.2	9.8	6.9
150, on 200	18.5	4.4	88.5	11.5	3.9
200	39.3	a 9.4			0.0
	420.3	100.0			68.8

Total concentrates .... per cent .. 68.8
Slimes .... do 9.4
Tailings .... do 21.8
100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 8. FRANK WHITE MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	110.2	25.7	75.4	24.6	19.4
28, on 35	90.1	21.1	76.9	23.1	16.2
35, on 48	62.2	14.5	79.4	20.6	11.5
48, on 65	34.3	8.0	85.2	14.8	6.8
65, on 100	37.3	8.7	88.1	11.9	7.7
100, on 150	33.1	7.7	88.7	11.3	6.8
150, on 200	18.5	4.3	88.0	12.0	3.8
200	42.8	a 10.0			0.0
	428.5	100.0			72.2

Total concentrates .... per cent .. 72.2
Slimes .... do 10.0
Tailings .... do 17.8

100.0

SAMPLE 9. FRANK WHITE MINE.

Through 20, on 28	113.7	28.4	50.1	49.9	14.2
28, on 35	93.9	23.4	52.5	47.5	12.3
35, on 48	49.1	12.3	65.6	34.4	8.1
48, on 65	27.6	6.9	76.9	23.1	5.3
65, on 100	32.5	8.1	78.6	21.4	6.4
100, on 150	28.4	7.1	80.6	19.4	5.7
150, on 200	18.6	4.6	78.2	21.8	3.6
200	36.9	a 9.2			0.0
	400.7	100.0			55.6

Total concentrates .... per cent .. 55.6
Slimes .... do 9.2
Tailings .... do 35.2

100.0

SAMPLE 10. FRANK WHITE MINE.

Through 20, on 28	51.9	12.7	98.4	1.6	12.5
28, on 35	55.6	13.6	96.5	3.5	13.1
35, on 48	56.2	13.7	92.9	7.1	12.7
48, on 65	40.5	10.0	88.8	11.2	8.9
65, on 100	65.2	15.9	70.0	30.0	11.1
100, on 150	45.5	11.1	76.3	23.7	8.5
150, on 200	23.2	5.7	85.6	14.4	4.9
200	71.0	a 17.3			0.0
	409.1	100.0			71.7

Total concentrates .... per cent .. 71.7
Slimes .... do 17.3
Tailings .... do 11.0

100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 10. FRANK WHITE MINE (UNDER 35 MESH).

Screen analysis. Size of mesh.	Quantity taken for separation.		Separation. Concentrates.	Separation. Tailings.	Concentrates.
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 35, on 48	26.9	19.1	92.7	7.3	17.7
48, on 65	21.6	15.1	88.9	11.1	13.4
65, on 100	28.2	20.0	69.7	30.3	13.9
100, on 150	20.9	14.8	81.4	18.6	12.0
150, on 200	10.3	7.3	92.3	7.7	6.7
200	33.5	*a* 23.7	....	....	0.0
	141.4	100.0	....	....	63.7

Total concentrates	per cent..	63.7
Slimes	do....	23.7
Tailings	do....	12.6
		100.0

SAMPLE 11. RUFFNER MINE.

Size of mesh.	Grams.	Per cent.	Concentrates.	Tailings.	Concentrates.
Through 20, on 28	37.8	10.2	51.0	49.0	5.2
28, on 35	37.8	10.2	49.2	50.8	5.0
35, on 48	52.7	14.1	49.5	50.5	7.0
48, on 65	68.8	18.5	50.8	49.2	9.4
65, on 100	79.0	21.2	50.2	49.8	10.6
100, on 150	36.3	9.7	59.1	40.9	5.7
150, on 200	17.7	4.7	66.3	33.7	3.1
200	42.6	*a* 11.4	....	....	0.0
	372.7	100.0	....	....	46.0

Total concentrates	per cent..	46.0
Slimes	do....	11.4
Tailings	do....	42.6
		100.0

SAMPLE 11. RUFFNER MINE (UNDER 35 MESH).

Size of mesh.	Grams.	Per cent.	Concentrates.	Tailings.	Concentrates.
Through 35, on 48	35.0	16.5	40.1	59.9	6.6
48, on 65	41.3	19.5	44.1	55.9	8.6
65, on 100	62.3	29.4	42.6	57.4	12.5
100, on 150	25.0	11.8	49.7	50.3	5.9
150, on 200	12.2	5.8	67.3	32.7	3.9
200	36.1	*a* 17.0	....	....	0.0
	211.9	100.0	....	....	37.5

Total concentrates	per cent..	37.5
Slimes	do....	17.0
Tailings	do....	45.5
		100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 12. SPAULDING MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	110.5	26.6	61.8	38.2	16.4
28, on 35	101.7	24.5	66.4	33.6	16.3
35, on 48	65.9	15.9	75.4	24.6	12.0
48, on 65	31.8	7.6	77.5	22.5	5.9
65, on 100	32.5	7.8	78.3	21.7	6.1
100, on 150	26.4	6.4	78.3	21.7	5.0
150, on 200	15.4	3.6	80.4	19.6	2.9
200	31.6	*a*7.6			0.0
	415.8	100.0			64.6

Total concentrates per cent	64.6
Slimes do	7.6
Tailings do	27.8
	100.0

SAMPLE 13. SPAULDING MINE.

Through 20, on 28	118.7	27.4	61.2	38.8	16.8
28, on 35	99.3	22.9	69.0	31.0	15.8
35, on 48	65.5	15.1	73.7	26.3	11.1
48, on 65	35.0	8.0	78.2	21.8	6.3
65, on 100	34.4	7.9	77.1	22.9	6.1
100, on 150	28.2	6.5	79.0	21.0	5.1
150, on 200	17.0	3.9	82.3	17.7	3.2
200	35.8	*a*8.3			0.0
	433.9	100.0			64.4

Total concentrates per cent	64.4
Slimes do	8.3
Tailings do	27.3
	100.0

SAMPLE 14. SPAULDING MINE.

Through 20, on 28	101.0	25.4	61.0	39.0	15.5
28, on 35	88.2	22.2	68.7	31.3	15.3
35, on 48	61.5	15.5	74.0	26.0	11.5
48, on 65	34.7	8.7	75.5	24.5	6.6
65, on 100	34.1	8.5	75.0	25.0	6.4
100, on 150	23.2	5.8	76.0	24.0	4.4
150, on 200	18.8	4.7	76.6	23.4	3.6
200	36.5	*a*9.2			0.0
	398.0	100.0			63.3

Total concentrates per cent	63.3
Slimes do	9.2
Tailings do	27.5
	100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 14. SPAULDING MINE (UNDER 35 MESH).

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 35, on 48	63.0	28.2	65.1	34.9	18.4
48, on 65	45.0	15.6	68.8	31.2	10.7
65, on 100	36.6	16.4	66.4	33.6	10.9
100, on 150	25.4	11.3	67.5	32.5	7.6
150, on 200	15.8	7.1	71.9	28.1	5.1
200	47.9	[a] 21.4			0.0
	223.7	100.0			52.7

Total concentrates .... per cent.. 52.7
Slimes .... do.... 21.4
Tailings .... do.... 25.9
100.0

SAMPLE 15. SPAULDING MINE.

Through 20, on 28	112.4	27.7	66.6	33.4	18.5
28, on 35	88.6	21.8	68.4	31.6	14.9
35, on 48	61.9	15.2	75.6	24.4	11.5
48, on 65	28.5	7.0	76.0	24.0	5.3
65, on 100	31.9	7.8	77.4	22.6	6.0
100, on 150	26.1	6.4	77.5	22.5	5.0
150, on 200	17.0	4.2	75.6	24.4	3.2
200	39.1	[a] 9.9			0.0
	405.5	100.0			64.4

Total concentrates .... per cent.. 64.4
Slimes .... do.... 9.9
Tailings .... do.... 25.7
100.0

SAMPLE 16. SPAULDING MINE.

Through 20, on 28	110.5	24.7	61.7	38.3	15.2
28, on 35	99.0	22.1	70.5	29.5	15.6
35, on 48	67.7	15.1	74.8	25.2	11.3
48, on 65	41.0	9.2	78.9	21.1	7.9
65, on 100	40.5	9.0	77.8	22.2	7.0
100, on 150	27.6	6.2	76.6	23.4	4.7
150, on 200	18.5	4.1	77.2	22.8	3.2
200	43.1	[a] 9.6			0.0
	447.9	100.0			64.9

Total concentrates .... per cent.. 64.9
Slimes .... do.... 9.6
Tailings .... do.... 25.5
100.0

[a] Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 17. SPAULDING MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	110.0	24.2	61.1	38.9	14.4
28, on 35	99.9	22.0	65.5	34.5	14.2
35, on 48	74.2	16.4	74.2	25.8	12.2
48, on 65	36.1	8.0	78.1	21.9	6.4
65, on 100	39.0	8.6	74.6	25.4	6.2
100, on 150	31.8	7.0	73.6	26.4	5.
150, on 200	20.0	4.4	77.5	22.5	3.4
200	42.5	[a] 9.4			0.0
	453.5	100.0			62.6

Total concentrates	per cent	62.6
Slimes	do	9.4
Tailings	do	28.0
		100.0

SAMPLE 18. ISHKOODA MINE.

Through 20, on 28	87.1	25.7	67.2	32.8	17.3
28, on 35	77.4	22.8	71.8	28.2	16.4
35, on 48	52.0	15.3	74.5	25.5	11.4
48, on 65	31.6	9.3	75.3	24.7	7.0
65, on 100	27.7	8.2	77.2	22.8	6.3
100, on 150	19.9	5.9	72.6	27.4	4.3
150, on 200	11.8	3.4	73.8	26.2	2.5
200	31.9	[a] 9.4			0.0
	339.4	100.0			65.2

Total concentrates	per cent	65.2
Slimes	do	9.4
Tailings	do	25.4
		100.0

SAMPLE 19. ISHKOODA MINE.

Through 20, on 28	100.8	27.2	74.6	25.4	20.3
28, on 35	76.5	20.7	80.6	19.4	16.7
35, on 48	55.9	15.1	81.3	18.7	12.3
48, on 65	31.2	8.4	76.3	23.7	6.4
65, on 100	29.8	8.0	77.0	23.0	6.2
100, on 150	24.2	6.5	80.0	20.0	5.2
150, on 200	14.4	3.9	80.4	19.6	3.1
200	37.8	[a] 10.2			0.0
	370.6	100.0			70.2

Total concentrates	per cent	70.2
Slimes	do	10.2
Tailings	do	19.6
		100.0

[a] Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 20. ISHKOODA MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	81.5	28.6	57.8	42.2	16.5
28, on 35	67.1	23.6	72.8	27.2	17.2
35, on 48	39.9	14.0	68.9	31.1	9.6
48, on 65	22.0	7.7	69.0	31.0	5.3
65, on 100	22.0	7.7	67.1	32.9	5.2
100, on 150	16.3	5.7	70.3	29.7	4.0
150, on 200	9.5	3.3	80.2	19.8	2.6
200	26.8	*a* 9.4			0.0
	285.1	100.0			60.4

Total concentrates ... per cent	60.4
Slimes ... do	9.4
Tailings ... do	30.2
	100.0

SAMPLE 20. ISHKOODA MINE (UNDER 35 MESH).

Through 35, on 48	65.6	28.2	58.5	41.5	16.5
48, on 65	36.6	15.7	57.9	42.1	9.1
65, on 100	35.7	15.4	60.1	39.9	9.3
100, on 150	29.9	12.9	64.3	35.7	8.3
150, on 200	15.8	6.8	65.1	34.9	4.4
200	48.9	*a* 21.0			0.0
	232.5	100.0			47.6

Total concentrates ... per cent	47.6
Slimes ... do	21.0
Tailings ... do	31.4
	100.0

SAMPLE 21. ISHKOODA MINE.

Through 20, on 28	48.7	19.7	75.4	24.6	14.9
28, on 35	52.1	21.1	80.5	19.5	17.0
35, on 48	40.2	16.3	82.1	17.9	13.4
48, on 65	22.6	9.1	81.5	18.5	7.4
65, on 100	22.0	8.9	79.7	20.3	7.1
100, on 150	19.4	7.8	82.8	17.2	6.5
150, on 200	11.3	4.6	75.8	24.2	3.5
200	30.9	*a* 12.5			0.0
	247.2	100.0			69.8

Total concentrates ... per cent	69.8
Slimes ... do	12.5
Tailings ... do	17.7
	100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 22. ISHKOODA MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	120.2	27.5	70.0	30.0	19.3
28, on 35	94.9	21.7	77.1	22.9	16.7
35, on 48	70.6	16.2	81.1	18.9	13.1
48, on 65	42.3	9.7	78.3	21.7	7.6
65, on 100	32.8	7.5	76.7	23.3	5.8
100, on 150	27.7	6.4	77.4	22.6	4.9
150, on 200	14.5	3.3	82.7	17.3	2.7
200	33.5	a 7.7			0.0
	436.5	100.0			70.1

Total concentrates	per cent..	70.1
Slimes	do....	7.7
Tailings	do....	22.2
		100.0

SAMPLE 23. SONGO MINE.

Size of mesh.	Grams.	Per cent.	Concentrates.	Tailings.	Concentrates.
Through 20, on 28	90.9	25.4	63.5	36.5	16.1
28, on 35	79.0	22.1	68.9	31.1	15.1
35, on 48	53.9	15.1	72.7	27.3	11.0
48, on 65	30.4	8.5	75.8	24.2	6.5
65, on 100	31.4	8.8	76.8	23.2	6.8
100, on 150	23.8	6.6	76.0	24.0	5.0
150, on 200	12.6	3.5	76.0	24.0	2.6
200	36.0	a 10.0			0.0
	358.0	100.0			63.1

Total concentrates	per cent..	63.1
Slimes	do....	10.0
Tailings	do....	26.8
		99.9

SAMPLE 24. SONGO MINE.

Size of mesh.	Grams.	Per cent.	Concentrates.	Tailings.	Concentrates.
Through 20, on 28	95.1	25.4	74.6	25.4	18.9
28, on 35	75.7	20.2	76.7	23.3	15.5
35, on 48	54.9	14.7	78.4	21.6	11.5
48, on 65	33.2	8.9	79.3	20.7	7.1
65, on 100	34.0	9.1	78.2	21.8	7.1
100, on 150	27.7	7.4	75.7	24.3	5.6
150, on 200	12.5	3.3	79.4	20.6	2.6
200	40.8	a 11.0			0.0
	373.9	100.0			68.3

Total concentrates	per cent..	68.3
Slimes	do....	11.0
Tailings	do....	20.7
		100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 25. SONGO MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	88.4	22.9	72.8	27.2	16.7
28, on 35	77.4	20.0	75.1	24.9	15.0
35, on 48	59.5	15.4	78.0	22.0	12.0
48, on 65	34.4	8.9	77.7	22.3	6.9
65, on 100	35.6	9.2	72.3	27.7	6.6
100, on 150	27.5	7.1	77.2	22.8	5.5
150, on 200	17.3	4.5	75.7	24.3	3.4
200	46.1	a 12.0			0.0
	386.2	100.0			66.1

Total concentrates	per cent	66.1
Slimes	do	12.0
Tailings	do	21.9
		100.0

SAMPLE 26. SONGO MINE.

Through 20, on 28	96.3	25.3	67.3	32.7	17.0
28, on 35	86.7	22.8	72.5	27.5	16.5
35, on 48	57.5	15.1	74.5	25.5	11.2
48, on 65	31.6	8.3	77.1	22.9	6.4
65, on 100	30.7	8.1	74.5	25.5	6.0
100, on 150	25.3	6.6	74.7	25.3	4.9
150, on 200	13.1	3.4	80.0	20.0	2.8
200	39.6	a 10.4			0.0
	380.8	100.0			64.8

Total concentrates	per cent	64.8
Slimes	do	10.4
Tailings	do	24.8
		100.0

SAMPLE 27. SONGO MINE.

Through 20, on 28	109.9	26.2	71.6	28.4	18.8
28, on 35	92.5	22.0	75.8	24.2	16.7
35, on 48	63.6	15.1	78.3	21.7	11.8
48, on 65	36.0	8.6	78.3	21.7	6.7
65, on 100	35.8	8.5	78.0	22.0	6.6
100, on 150	25.1	6.0	75.2	24.8	4.5
150, on 200	15.1	3.6	86.0	14.0	3.1
200	42.2	a 10.0			0.0
	420.0	100.0			68.2

Total concentrates	per cent	68.2
Slimes	do	10.0
Tailings	do	21.8
		100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 27. SONGO MINE (UNDER 35 MESH).

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 35, on 48	72.2	27.8	70.2	29.8	19.5
48, on 65	41.8	16.1	71.7	28.3	11.5
65, on 100	42.1	16.2	69.0	31.0	11.2
100, on 150	30.3	11.6	69.7	30.3	8.1
150, on 200	18.7	7.2	76.6	23.4	5.5
200	54.9	*a* 21.1			0.0
	260.0	100.0			55.8

Total concentrates ... per cent	55.8
Slimes ... do	21.1
Tailings ... do	23.1
	100.0

SAMPLE 28. SONGO MINE.

Through 20, on 28	108.2	25.0	71.0	29.0	17.8
28, on 35	93.1	21.5	76.0	24.0	16.3
35, on 48	70.5	16.3	79.9	20.1	13.0
48, on 65	40.5	9.4	80.0	20.0	7.5
65, on 100	35.4	8.2	78.4	21.6	6.4
100, on 150	26.4	6.1	78.6	21.4	4.8
150, on 200	19.0	4.4	80.7	19.3	3.6
200	39.4	*a* 9.1			0.0
	432.5	100.0			69.4

Total concentrates ... per cent	69.4
Slimes ... do	9.1
Tailings ... do	21.5
	100.0

SAMPLE 29. FOSSIL MINE.

Through 20, on 28	93.7	19.0	75.5	24.5	14.3
28, on 35	106.4	21.4	81.8	18.2	17.5
35, on 48	74.9	15.1	80.6	19.4	12.2
48, on 65	49.5	9.9	83.1	16.9	8.2
65, on 100	46.1	9.2	80.3	19.7	7.4
100, on 150	41.2	8.3	83.8	16.2	7.0
150, on 200	29.1	5.8	84.3	15.7	4.9
200	56.2	*a* 11.3			0.0
	497.1	100.0			71.5

Total concentrates ... per cent	71.5
Slimes ... do	11.3
Tailings ... do	17.2
	100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 29. FOSSIL MINE (UNDER 35 MESH).

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 35, on 48	50.4	25.8	77.6	22.4	20.0
48, on 65	31.9	16.4	76.3	23.7	12.5
65, on 100	29.6	15.2	73.0	27.0	11.1
100, on 150	23.5	12.0	74.9	25.1	9.0
150, on 200	15.9	8.1	71.9	28.1	5.8
200	43.8	*a* 22.5			0.0
	195.1	100.0			58.4

Total concentrates	per cent	58.4
Slimes	do	22.5
Tailings	do	19.1
		100.0

SAMPLE 30. FOSSIL MINE.

Through 20, on 28	108.3	24.4	69.0	31.0	16.8
28, on 35	101.5	22.9	75.9	24.1	17.4
35, on 48	70.5	15.9	77.7	22.3	12.4
48, on 65	40.1	9.0	77.5	22.5	7.0
65, on 100	40.0	9.0	74.4	25.6	6.7
100, on 150	29.2	6.6	76.1	23.9	5.0
150, on 200	17.2	3.9	76.6	23.4	3.0
200	36.8	*a* 8.3			0.0
	443.6	100.0			68.3

Total concentrates	per cent	68.3
Slimes	do	8.3
Tailings	do	23.4
		100.0

SAMPLE 31. FOSSIL MINE.

Through 20, on 28	106.3	25.3	67.3	32.7	17.0
28, on 35	92.9	22.1	74.6	25.4	16.5
35, on 48	64.2	15.3	77.6	22.4	11.9
48, on 65	36.5	8.7	77.8	22.2	6.8
65, on 100	36.6	8.7	77.1	22.9	6.7
100, on 150	30.3	7.2	75.3	24.7	5.4
150, on 200	16.0	3.8	74.7	25.3	2.8
200	37.5	*a* 8.9			0.0
	420.3	100.0			67.1

Total concentrates	per cent	67.1
Slimes	do	8.9
Tailings	do	24.0
		100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 32. FOSSIL MINE.

Screen analysis.			Separation.		
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	Concentrates.
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	109.5	27.4	77.0	23.0	21.1
28, on 35	80.0	20.0	81.8	18.2	16.4
35, on 48	54.7	13.7	78.4	21.6	10.7
48, on 65	33.8	8.5	77.7	22.3	6.6
65, on 100	32.8	8.2	76.2	23.8	6.2
100, on 150	30.4	7.6	75.6	24.4	5.7
150, on 200	19.7	4.9	78.1	21.9	3.8
200	38.6	[a] 9.7			0.0
	399.5	100.0			70.5

Total concentrates per cent	70.5
Slimes do	9.7
Tailings do	19.8
	100.0

SAMPLE 33. FOSSIL MINE.

Through 20, on 28	96.8	25.7	69.8	30.2	17.9
28, on 35	82.6	21.9	78.1	21.9	17.1
35, on 48	58.5	15.5	80.7	19.3	12.5
48, on 65	34.6	9.2	80.8	19.3	7.4
65, on 100	30.5	8.1	79.1	20.9	6.4
100, on 150	25.5	6.7	79.6	20.4	5.3
150, on 200	14.2	3.7	77.3	22.7	2.9
200	34.8	[a] 9.2			0.0
	377.5	100.0			69.5

Total concentrates per cent	69.5
Slimes do	9.2
Tailings do	21.3
	100.0

SAMPLE 34. FOSSIL MINE.

Through 20, on 28	106.2	25.8	63.8	36.2	16.5
28, on 35	88.4	21.4	72.7	27.3	15.6
35, on 48	64.3	15.6	75.4	24.6	11.8
48, on 65	36.2	8.8	73.9	26.1	6.5
65, on 100	33.9	8.2	73.7	26.3	6.0
100, on 150	26.9	6.5	74.2	25.8	4.8
150, on 200	16.9	4.1	75.9	24.1	3.1
200	39.7	[a] 9.6			0.0
	412.5	100.0			64.3

Total concentrates per cent	64.3
Slimes do	9.6
Tailings do	26.1
	100.0

[a] Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 35. RUFFNER MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	129.3	27.1	70.9	29.1	19.2
28, on 35	113.4	23.8	78.5	21.5	18.7
35, on 48	78.5	16.5	78.2	21.8	12.9
48, on 65	35.6	7.5	77.6	22.4	5.8
65, on 100	37.7	7.9	77.0	23.0	6.1
100, on 150	25.6	5.4	76.7	23.3	4.1
150, on 200	19.5	4.0	80.0	20.0	3.2
200	37.4	a 7.8			0.0
	477.0	100.0			70.0

Total concentrates per cent	70.0
Slimes do	7.8
Tailings do	22.2
	100.0

SAMPLE 36. RUFFNER MINE.

Through 20, on 28	95.2	25.3	66.4	33.6	16.8
28, on 35	79.2	21.0	74.4	25.6	15.6
35, on 48	53.0	14.1	74.7	25.3	10.5
48, on 65	34.5	9.2	72.0	28.0	6.6
65, on 100	34.7	9.2	70.7	29.3	6.5
100, on 150	25.9	6.9	70.5	29.5	4.9
150, on 200	16.7	4.4	70.0	30.0	3.1
200	37.1	a 9.9			0.0
	376.3	100.0			64.0

Total concentrates per cent	64.0
Slimes do	9.9
Tailings do	26.1
	100.0

SAMPLE 37. HAMMOND MINE.

Through 20, on 28	103.6	25.8	74.5	25.5	19.2
28, on 35	92.4	23.0	83.8	16.2	19.3
35, on 48	61.7	15.3	80.4	19.6	12.3
48, on 65	32.3	8.0	80.5	19.5	6.4
65, on 100	32.6	8.1	82.6	17.4	6.7
100, on 150	27.4	6.8	84.7	15.3	5.8
150, on 200	14.1	3.5	91.4	8.6	3.2
200	38.2	a 9.5			0.0
	402.3	100.0			72.9

Total concentrates per cent	72.9
Slimes do	9.5
Tailings do	17.6
	100.0

a Slimes.

TABLE 1.—*Results of crushing and separating samples from various mines*—Continued.

SAMPLE 38. RUFFNER MINE.

Screen analysis.			Separation.		Concentrates.
Size of mesh.	Quantity taken for separation.		Concentrates.	Tailings.	
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Through 20, on 28	103.9	29.7	39.2	60.8	11.6
28, on 35	86.1	24.6	42.8	57.2	10.5
35, on 48	48.4	13.8	51.6	48.4	7.1
48, on 65	24.6	7.0	60.3	39.7	4.2
65, on 100	25.9	7.0	65.4	34.6	4.8
100, on 150	20.2	5.8	63.7	36.3	3.7
150, on 200	11.8	3.4	66.6	33.4	2.3
200	29.1	a 8.3	....	....	0.0
	350.0	99.6	....		44.2

Total concentrates............per cent 44.2
Slimes............do. 8.3
Tailings............do. 47.5

100.0

SAMPLE 39. HAMMOND MINE.

Through 20, on 28	81.3	20.7	74.8	25.2	15.5
28, on 35	88.1	22.4	66.7	33.3	14.9
35, on 48	60.1	15.3	61.0	39.0	9.3
48, on 65	33.2	8.7	86.5	13.5	7.5
65, on 100	39.7	10.1	89.6	10.4	9.0
100, on 150	30.6	7.7	91.3	8.7	7.0
150, on 200	16.4	4.1	90.4	9.6	3.7
200	43.6	a 11.0	....	....	0.0
	393.0	100.0	....	....	66.9

Total concentrates............per cent 66.9
Slimes............do. 11.0
Tailings............do. 22.1

100.0

a Slimes.

TABLE 2.—*Composition of products and recoveries of samples from various mines.*

SAMPLE 1. ISKOODA MINE.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Crude	32.1	10.3	21.1	100.0	100.0	....
Concentrates	43.5	7.0	12.6	80.7	38.2	1.74
Slimes	33.9	7.3	....	10.5	6.7	....
Tailings	8.2	17.6	....	8.8	55.1	....
Concentrates + slimes	42.1	7.0	....	91.2	44.9	1.49

SAMPLE 2. SPAULDING MINE.

Crude	[illegible]	20.5	11.1	100.0	100.0	....
Concentrates	[illegible]	10.9	18.5	85.6	34.4	1.46
Slimes	44.8	12.1	....	8.2	3.8	....
Tailings	9.2	49.6	....	6.2	61.8	....
Concentrates + slimes	46.1	11.0	....	93.8	38.2	1.33

TABLE 2.—*Composition of products and recoveries of samples from various mines*—Continued.

SAMPLE 3. SPAULDING MINE.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Crude	35.7	15.0	....	100.0	100.0	....
Concentrates	46.2	7.9	....	83.8	34.3	1.54
Slimes	40.0	8.9	....	10.3	5.5	....
Tailings	8.2	34.7	....	5.9	60.2	....
Concentrates+slimes	45.4	8.0	....	94.1	39.8	1.35

SAMPLE 4. HAMMOND MINE.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
Crude	37.2	40.3	....	100.0	100.0	....
Concentrates	52.4	17.5	....	80.7	21.5	1.85
Slimes	47.1	23.9	....	12.1	4.9	....
Tailings	6.8	87.2	....	7.2	73.6	....
Concentrates+slimes	51.7	18.4	....	92.8	26.4	1.59

SAMPLE 5. RUFFNER MINE.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
Crude	28.8	31.8	10.2	100.0	100.0	....
Concentrates	40.2	20.2	6.9	71.2	30.2	2.07
Slimes	40.4	11.6	....	16.4	4.0	....
Tailings	8.7	55.1	....	12.4	65.8	....
Concentrates+slimes	40.3	18.6	....	87.6	34.2	1.65

SAMPLE 6. RUFFNER MINE.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
Crude	28.8	29.9	....	100.0	100.0	....
Concentrates	43.7	16.7	....	64.0	22.3	2.44
Slimes	34.5	13.0	....	24.4	8.4	....
Tailings	8.3	54.4	....	11.6	69.3	....
Concentrates+slimes	40.7	15.5	....	88.4	30.7	1.65

SAMPLE 7. FRANK WHITE MINE.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
Crude	45.2	26.1	....	100.0	100.0	....
Concentrates	53.6	13.4	....	84.1	32.8	1.45
Slimes	53.7	12.7	....	11.5	4.2	....
Tailings	8.9	81.2	....	4.4	63.0	....
Concentrates+slimes	53.6	13.3	....	95.6	37.0	1.28

SAMPLE 8. FRANK WHITE MINE.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
Crude	44.0	24.5	....	100.0	100.0	....
Concentrates	52.3	12.7	....	84.9	37.8	1.39
Slimes	53.0	11.3	....	11.9	4.6	....
Tailings	8.0	78.6	....	3.2	57.6	....
Concentrates+slimes	52.4	12.5	....	96.8	42.4	1.22

SAMPLE 9. FRANK WHITE MINE.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
Crude	36.3	41.0	....	100.0	100.0	....
Concentrates	49.8	19.7	....	80.3	25.1	1.80
Slimes	46.4	23.4	....	12.4	4.9	....
Tailings	7.2	86.9	....	7.3	70.0	....
Concentrates+slimes	49.3	20.2	....	92.7	30.0	1.54

TABLE 2.—*Composition of products and recoveries of samples from various mines*—Continued.

SAMPLE 10. FRANK WHITE MINE.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Crude	45.8	25.1	....	100.0	100.0	....
Concentrates	49.8	19.1	....	69.7	47.2	1.57
Slimes	53.7	12.7	....	28.0	11.7	....
Tailings	8.4	84.3	....	2.3	41.1	....
Concentrates+slimes	50.9	17.4	....	97.7	58.9	1.14

SAMPLE 11. RUFFNER MINE.

Crude	27.7	34.3	10.1	100.0	100.0	....
Concentrates	44.9	17.7	4.7	61.0	18.3	2.67
Slimes	39.1	11.7	....	24.6	5.5	....
Tailings	8.6	60.7	....	14.4	76.2	....
Concentrates+slimes	42.7	15.8	....	85.6	23.8	1.83

SAMPLE 12. SPAULDING MINE.

Crude	35.9	27.0	....	100.0	100.0	....
Concentrates	45.5	11.9	....	83.1	27.7	1.55
Slimes	46.1	14.0	....	9.9	3.8	....
Tailings	8.9	68.4	....	7.0	68.5	....
Concentrates+slimes	45.6	12.1	....	93.0	31.5	1.39

SAMPLE 13. SPAULDING MINE.

Crude	36.8	26.2	7.5	100.0	100.0	....
Concentrates	45.6	13.2	7.6	82.1	30.8	1.55
Slimes	46.4	13.1	....	10.8	3.9	....
Tailings	9.3	66.0	....	7.1	65.3	....
Concentrates+slimes	45.7	13.2	....	92.9	34.7	1.38

SAMPLE 14. SPAULDING MINE.

Crude	35.3	27.7	....	100.0	100.0	....
Concentrates	45.1	13.5	....	81.4	30.4	1.58
Slimes	44.3	14.9	....	11.6	4.8	....
Tailings	8.7	66.3	....	7.0	64.8	....
Concentrates+slimes	44.9	13.6	....	93.0	35.2	1.38

SAMPLE 15. SPAULDING MINE.

Crude	36.5	26.1	....	100.0	100.0	....
Concentrates	45.0	14.0	....	81.4	32.8	1.55
Slimes	44.4	14.4	....	12.3	5.2	....
Tailings	8.7	66.6	....	6.3	62.0	....
Concentrates+slimes	44.9	14.1	....	93.7	38.0	1.35

SAMPLE 16. SPAULDING MINE.

Crude	36.9	26.1	....	100.0	100.0	....
Concentrates	44.9	13.1	....	81.2	31.1	1.54
Slimes	46.5	13.5	....	12.4	4.4	....
Tailings	9.0	69.1	....	6.4	64.5	....
Concentrates+slimes	45.1	13.0	....	93.6	35.5	1.34

TABLE 2. *Composition of products and recoveries of samples from various mines*—Continued.

SAMPLE 17, SPAULDING MINE.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Crude	35.0	27.5	....	100.0	100.0	....
Concentrates	47.7	12.3	....	82.3	27.8	1.60
Slimes	43.3	15.4	....	11.2	5.2	....
Tailings	8.4	66.4	....	6.5	67.0	....
Concentrates and slimes	47.1	12.7	....	93.5	33.0	1.39

AVERAGE OF SAMPLES 12 TO 17.

Crude	36.1	26.8	7.5	....	....	....
Concentrates	45.6	13.0	7.6	81.9	....	1.56
Slimes	45.2	14.2	....	....	....	....
Tailings	8.8	67.1	....	....	....	....
Concentrates and slimes	45.6	13.1	....	93.3	....	1.37

SAMPLE 18. ISHKOODA MINE.

Crude	33.5	29.7	8.0	100.0	100.0	....
Concentrates	43.7	14.2	7.7	80.6	33.9	1.55
Slimes	45.4	13.2	....	12.1	4.5	....
Tailings	10.2	66.5	....	7.3	61.6	....
Concentrates and slimes	43.9	14.0	....	92.7	38.4	1.34

SAMPLE 19. ISHKOODA MINE.

Crude	39.1	20.5	....	100.0	100.0	....
Concentrates	47.1	10.6	....	83.5	39.8	1.42
Slimes	45.3	10.6	....	11.6	5.8	....
Tailings	9.8	52.0	....	4.9	54.4	....
Concentrates and slimes	46.9	10.6	....	95.1	45.6	1.24

SAMPLE 20. ISHKOODA MINE.

Crude	32.4	29.3	....	100.0	100.0	....
Concentrates	42.3	16.1	....	80.0	34.5	1.66
Slimes	39.8	12.4	....	11.7	4.1	....
Tailings	8.8	57.3	....	8.3	61.4	....
Concentrates and slimes	42.0	15.6	....	91.7	38.6	1.44

SAMPLE 21. ISHKOODA MINE.

Crude	42.3	18.2	....	100.0	100.0	....
Concentrates	48.9	9.6	....	81.4	37.6	1.44
Slimes	49.0	11.2	....	14.6	7.8	....
Tailings	9.4	55.0	....	4.0	54.6	....
Concentrates and slimes	48.9	9.8	....	96.0	45.4	1.21

SAMPLE 22. ISHKOODA MINE.

Crude	38.3	20.2	....	100.0	100.0	....
Concentrates	46.2	11.3	....	85.9	37.7	1.43
Slimes	45.0	11.6	....	9.2	4.2	....
Tailings	8.4	55.0	....	4.9	58.1	....
Concentrates and slimes	46.1	11.3	....	95.1	41.9	1.30

TABLE 2.—*Composition of products and recoveries of samples from various mines*—Continued.

Products.	Fe.	SiO_2.	CaO.	Total iron.	Total silica.	Ratio of concentration.
AVERAGE OF SAMPLES 18 TO 22.						
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Crude	37.1	25.6	8.0	....	....	....
Concentrates	45.6	12.4	7.7	82.3	....	1.50
Slimes	44.9	11.8	....	....	....	....
Tailings	9.3	57.2	....	....	....	....
Concentrates and slimes	45.6	12.3	....	94.1	....	1.31
SAMPLE 23. SONGO MINE.						
Crude	37.1	21.8	....	100.0	100.0	....
Concentrates	45.4	12.7	....	81.1	32.0	1.58
Slimes	43.9	12.9	....	12.4	5.1	....
Tailings	8.6	58.8	....	6.5	62.9	....
Concentrates+slimes	45.2	12.7	....	93.5	37.1	1.37
SAMPLE 24. SONGO MINE.						
Crude	38.2	19.7	....	100.0	100.0	....
Concentrates	45.3	12.3	....	82.5	40.4	1.46
Slimes	44.1	11.2	....	12.9	5.9	....
Tailings	8.4	53.9	....	4.6	53.7	....
Concentrates+slimes	45.1	12.1	....	95.4	46.3	1.26
SAMPLE 25. SONGO MINE.						
Crude	39.1	21.9	....	100.0	100.0	....
Concentrates	46.2	12.6	....	78.1	37.9	1.51
Slimes	45.8	14.1	....	14.0	7.7	....
Tailings	11.1	54.4	....	7.9	54.4	....
Concentrates+slimes	46.1	12.8	....	92.1	45.6	1.28
SAMPLE 26. SONGO MINE.						
Crude	39.3	23.2	....	100.0	100.0	....
Concentrates	44.9	12.4	....	81.1	33.6	1.54
Slimes	43.7	13.5	....	12.7	5.8	....
Tailings	9.0	58.6	....	6.2	60.6	....
Concentrates+slimes	44.7	12.6	....	93.8	39.4	1.33
SAMPLE 27. SONGO MINE.						
Crude	37.2	21.1	10.5	100.0	100.0	....
Concentrates	43.5	13.2	9.5	83.2	37.5	1.47
Slimes	44.0	12.8	....	12.3	5.3	....
Tailings	7.4	63.0	....	4.5	57.2	....
Concentrates+slimes	43.6	13.1	....	95.5	42.8	1.28
SAMPLE 28. SONGO MINE.						
Crude	39.5	19.3	....	100.0	100.0	....
Concentrates	45.3	11.8	....	83.9	38.0	1.44
Slimes	47.4	11.7	....	11.5	4.9	....
Tailings	8.0	57.2	....	4.6	57.1	....
Concentrates+slimes	45.5	11.8	....	95.4	42.9	1.27

TABLE 2.—*Composition of products and recoveries of samples from various mines*—Continued.

Products.	Fe.	SiO$_2$.	CaO.	Total iron.	Total silica.	Ratio of concentration.
AVERAGE OF SAMPLES 23 TO 28.						
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Crude	38.4	21.2	10.5	....	....	....
Concentrates	45.1	12.5	9.5	81.7	....	1.50
Slimes	44.8	12.7	....	....	....	....
Tailings	9.3	57.7	....	....	....	....
Concentrates+slimes	45.0	12.5	....	94.3	....	1.30
SAMPLE 29. FOSSIL MINE.						
Crude	39.8	21.1	....	100.0	100.0	....
Concentrates	48.1	11.7	....	71.1	31.8	1.71
Slimes	43.8	16.6	....	25.0	17.4	....
Tailings	8.1	57.1	....	3.9	50.8	....
Concentrates+slimes	46.9	13.1	....	96.1	49.2	1.24
SAMPLE 30. FOSSIL MINE.						
Crude	37.8	22.0	....	100.0	100.0	....
Concentrates	46.0	11.9	....	84.5	36.2	1.46
Slimes	44.6	13.6	....	9.9	5.0	....
Tailings	8.9	56.3	....	5.6	58.8	....
Concentrates+slimes	45.8	12.1	....	94.4	41.2	1.31
SAMPLE 31. FOSSIL MINE.						
Crude	36.8	21.7	9.6	100.0	100.0	....
Concentrates	45.3	12.8	7.6	84.0	38.8	1.49
Slimes	43.0	13.7	....	10.6	5.5	....
Tailings	8.2	51.4	....	5.4	55.7	....
Concentrates+slimes	45.0	12.9	....	94.6	44.3	1.32
SAMPLE 32. FOSSIL MINE.						
Crude	39.4	18.6	....	100.0	100.0	....
Concentrates	46.2	11.9	....	84.7	42.4	1.42
Slimes	44.2	12.4	....	11.1	6.1	....
Tailings	8.3	51.5	....	4.2	51.5	....
Concentrates+slimes	46.0	12.0	....	95.8	48.5	1.35
SAMPLE 33. FOSSIL MINE.						
Crude	38.4	20.2	....	100.0	100.0	....
Concentrates	45.3	12.0	....	84.0	38.5	1.44
Slimes	45.5	11.3	....	11.2	4.8	....
Tailings	8.5	57.5	....	4.8	56.7	....
Concentrates+slimes	45.3	11.9	....	95.2	43.3	1.27
SAMPLE 34. FOSSIL MINE.						
Crude	35.6	21.5	....	100.0	100.0	....
Concentrates	44.9	12.2	....	82.4	35.3	1.56
Slimes	42.0	12.9	....	11.5	5.6	....
Tailings	8.2	50.4	....	6.1	59.1	....
Concentrates+slimes	44.5	12.3	....	93.9	38.9	1.35

TABLE 2.—*Composition of products and recoveries of samples from various mines*—Continued

Products	Fe	SiO_2	CaO.	Total iron.	Total silica.	Ratio of concentration.
AVERAGE OF SAMPLES 30 TO 34.						
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Crude	37.6	20.8	9.6	....	....	....
Concentrates	45.5	12.2	7.6	83.8	....	1.47
Slimes	43.9	12.8	....	....	....	....
Tailings	8.4	53.3	....	....	....	....
Concentrates+slimes	45.3	12.2	....	94.8	....	1.30
SAMPLE 35. RUFFNER MINE.						
Crude	38.1	22.1	....	100.0	100.0	....
Concentrates	45.1	13.7	....	85.4	40.4	1.43
Slimes	44.3	14.2	....	9.4	4.7	....
Tailings	8.6	58.6	....	5.2	54.9	....
Concentrates + slimes	44.9	13.8	....	94.8	45.1	1.29
SAMPLE 36. RUFFNER MINE.						
Crude	34.5	23.2	....	100.0	100.0	....
Concentrates	43.5	15.0	....	82.8	40.0	1.56
Slimes	40.4	13.3	....	11.9	5.5	....
Tailings	6.9	50.1	....	5.3	54.5	....
Concentrates + slimes	43.1	14.7	....	94.7	45.5	1.35
SAMPLE 37. HAMMOND MINE.						
Crude	41.5	20.9	....	100.0	100.0	....
Concentrates	46.8	14.0	....	84.6	45.3	1.37
Slimes	50.0	11.1	....	11.8	4.7	....
Tailings	8.4	64.1	....	3.6	50.0	....
Concentrates + slimes	47.2	13.7	....	96.4	50.0	1.21
SAMPLE 38. RUFFNER MINE.						
Crude	28.2	40.8	....	100.0	100.0	....
Concentrates	47.5	14.7	....	77.8	14.5	2.26
Slimes	38.9	23.8	....	12.0	4.4	....
Tailings	5.8	76.6	....	10.2	81.1	....
Concentrates + slimes	46.1	16.1	....	89.8	18.9	1.90
SAMPLE 39. HAMMOND MINE.						
Crude	46.2	28.0	....	100.0	100.0	....
Concentrates	55.2	14.6	....	82.9	32.1	1.50
Slimes	55.5	13.3	....	13.7	4.8	....
Tailings	6.8	87.1	....	3.4	63.1	....
Concentrates + slimes	55.3	14.4	....	96.6	36.9	1.28

NOTES ON SAMPLES.

ORE FROM THE BIG SEAM.

SAMPLE 1. ISHKOODA MINE.

Sample 1 was taken in No. 13 slope, 6 right heading, near the manway. The upper bench is here underlaid with a ½-inch shale parting and is 7 feet thick. The sample was taken across the entire bench.

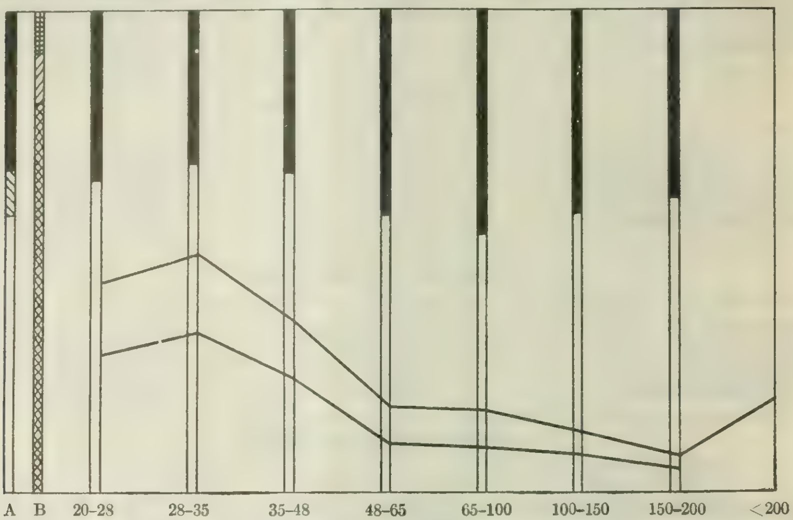

FIGURE 1.—Results of tests of sample 1.[a]

SAMPLE 2. SPAULDING MINE.

Sample 2, from 1 left heading, cross left, 700 feet from slope. The Big seam has no parting in this mine, so that the lower limit of the upper bench is an arbitrary line, and the upper 11 feet of the seam were mined when the mine was working. The sample represents the entire 11 feet of workable ore.

SAMPLE 3. SPAULDING MINE.

Sample 3 was taken from 3 left heading at the breast and represents the upper 12 feet of the seam or the part that was worked at this point.

Instead of the concentrates and tailings for the entire sample being analyzed, the concentrates and tailings for each mesh size were analyzed, and the composition of the concentrates and tailings, as given above, was calculated from these results. The analyses of the

[a] In figs. 1 to 47, column A shows, in upward order, the percentage of concentrate, slime, and tailing from the sample, and column B the percentage in each of the total iron in the sample. Upper broken curve shows proportion of total crushed ore in each size; lower broken curve shows actual quantity of concentrate from each size. See p. 15.

products obtained from the different mesh sizes follow. For each mesh size the percentage of the total iron that went into the con-

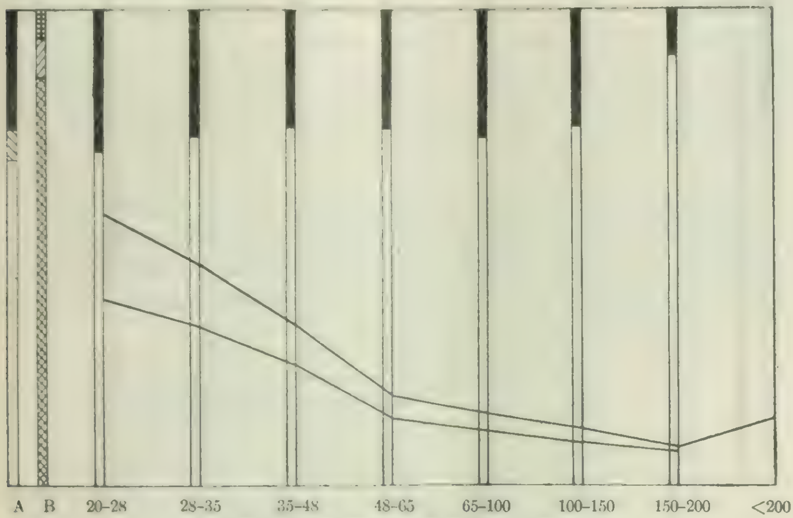

FIGURE 2.—Results of tests of sample 2.

centrates and the tailings in that size is given, and also the composition of the crude ore of each size.

Composition of concentrates and tailings by mesh sizes.

Size of mesh.	Concentrates.		Tailings.		Crude.		Total iron in—	
	Fe.	SiO_2.	Fe.	SiO_2.	Fe.	SiO_2.	Concentrates.	Tailings.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
20 to 28	42.9	9.5	9.3	44.7	32.5	20.5	91.1	8.9
28 to 35	45.7	8.1	10.0	36.9	36.1	15.9	92.6	7.4
35 to 48	46.4	7.6	8.9	33.5	37.1	14.0	94.0	6.0
48 to 65	46.8	6.9	8.1	25.0	35.0	12.4	93.0	7.0
65 to 100	47.5	6.9	6.4	24.9	35.3	12.2	94.7	5.3
100 to 150	51.7	6.1	6.6	22.5	38.4	10.9	95.0	5.0
150 to 200	55.1	5.7	9.0	20.0	42.3	9.7	94.1	5.9
200	....	....	....	....	40.0	8.9	....	....

The above table shows that the 20 to 28 mesh crude ore is of decidedly lower grade than the original ore, the 28 to 35 mesh size is of about the same grade, and the smaller sizes are all better than the original, there being a nearly constant increase in grade for each successively smaller size. If at the outset of concentration the 20 to 28 mesh size were rejected and thrown into the tailings, with a ratio of concentration of 2.11 and and an iron recovery of 62.8 per cent, one would obtain a concentrate running 47.4 per cent Fe and 7.3

per cent SiO_2. In other words, the compensation for a decrease in iron recovery of 21 per cent would be by only an increase of 1.2 per

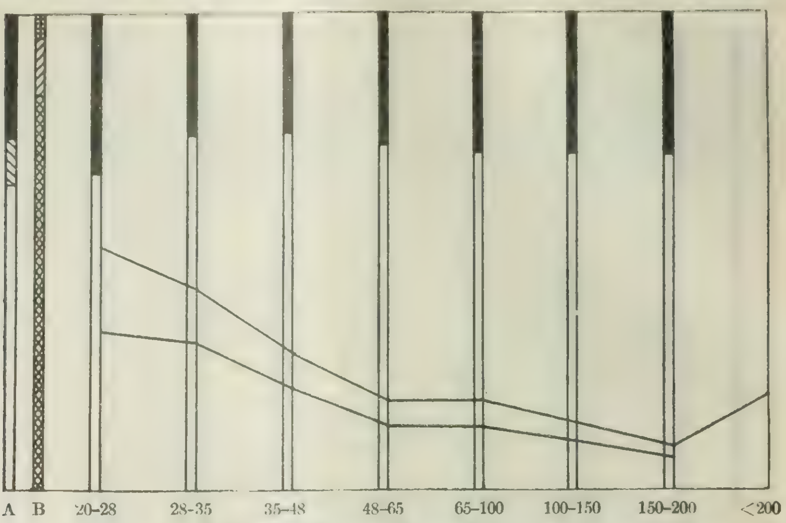

FIGURE 3. Results of tests of sample 3.

cent iron and a decrease of 0.6 per cent silica in the concentrates, not enough to warrant the procedure.

SAMPLE 4. HAMMOND MINE.

The Big seam was not worked at this mine, but it is cut by an adit driven to reach the slope on the Irondale seam, and the sample was

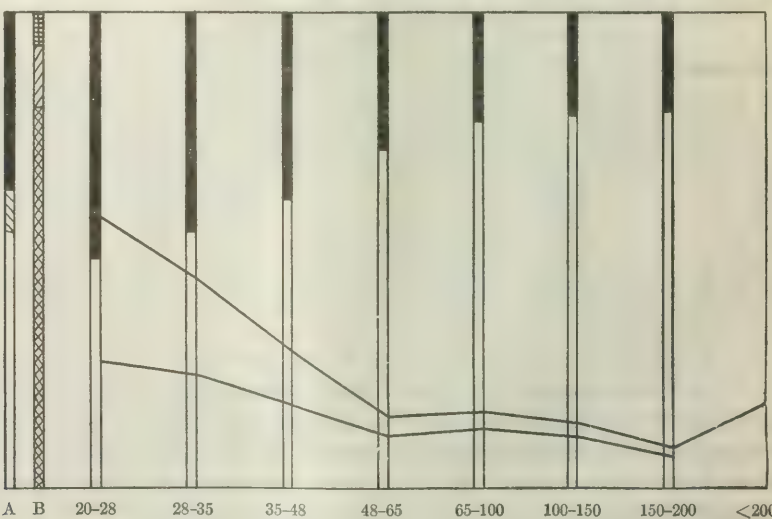

FIGURE 4.—Results of tests of sample 4.

taken from the exposure in this adit. The seam here is only a few feet from the surface, and the ore corresponds more nearly to soft ore. The sample was taken across the entire seam.

SAMPLE 5. RUFFNER MINE.

The Big seam in the Ruffner mine is about 18 feet thick, the upper 7 feet being workable, and is overlain by what is called "honeycomb" rock, which is really a low-grade ore high in silica with considerable visible calcite. The sample was taken from the 7 feet of workable ore at the bottom of the slope at heading 10 left. The ore is unusually fine grained, as is shown by the screen-analysis curves (figs. 5 to 8).

Because the ore was so fine grained another part of the sample was crushed to pass 35 mesh and subjected to separation. The results of this test, given in Table 1 (p. 19), show a screen-analysis curve (fig. 6) of the same character as that from the 20-mesh test and the

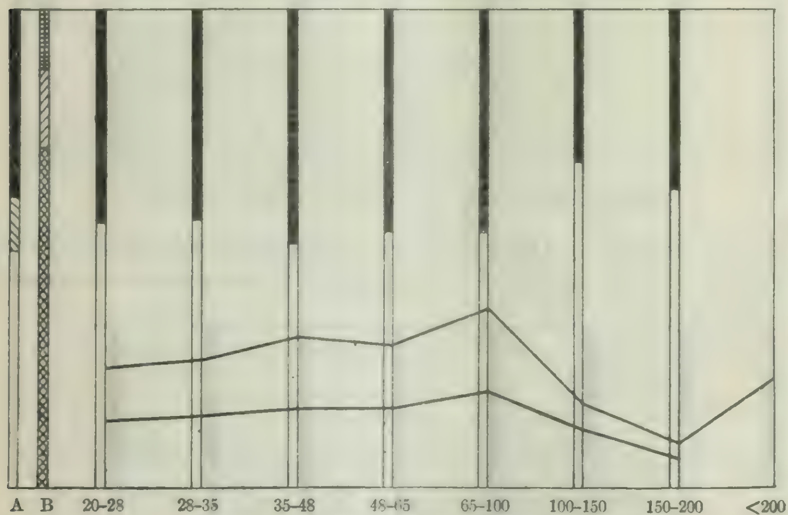

FIGURE 5.—Results of tests of sample 5.

same percentage of tailings in the concentration tests. The only evident change is an increase of slimes and a decrease in the quantity of concentrates with finer crushing. Though no analysis was made of the products, the various percentages seem to indicate that little was gained by the finer crushing.

SAMPLE 6. RUFFNER MINE.

Sample 6 was taken from 4 left heading, 400 feet from the slope, and represents the upper 7 feet of ore. This ore is very fine grained, as the screen-analysis curves indicate. Only the concentrates from this separation were analyzed. They carried 42.5 per cent Fe and 20.6 per cent SiO_2. Another part of this sample was crushed under 35 mesh and concentrated; the results are given on page 20.

Crushing this sample finer than 35 mesh increased the ratio of concentration from 1.64 to 2.44, and correspondingly increased the grade

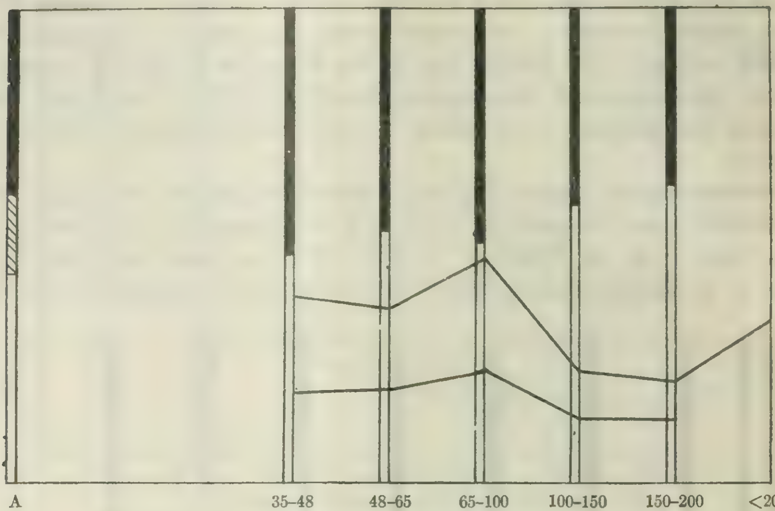

FIGURE 6.—Results of tests of sample 5 under 35 mesh.

of the concentrates. The increase of slimes leaves the advantage still decidedly in favor of the 35-mesh size, for if the slimes are added to

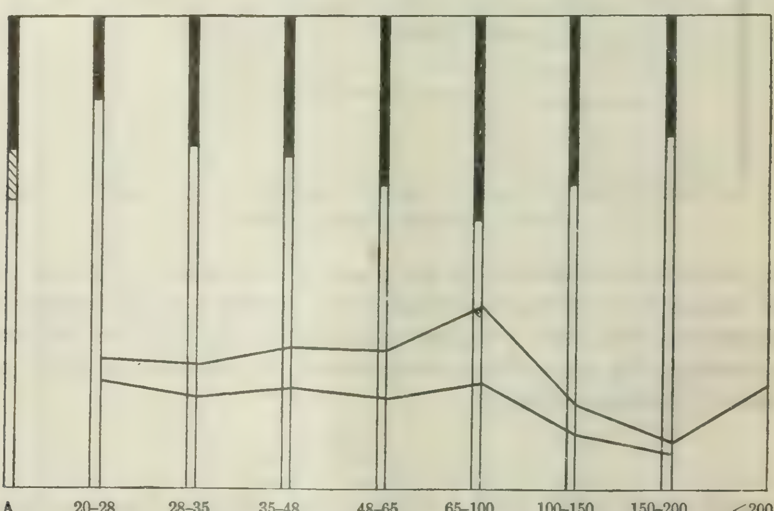

FIGURE 7.—Results of tests of sample 6.

the concentrates the ratio of concentration becomes 1.65, which is practically that of the concentrates in the 20-mesh size, and yet the

composition of the combined product runs only 1.5 per cent less in iron and 5 per cent less in silica. If the slimes are rejected and only the concentrates considered, the finer crushing yields a product 1.2 per cent higher in iron and 3.9 per cent lower in silica, but decreases the iron recovery to 64 per cent.

COMMENTS ON TESTS OF UPPER BENCH ORE.

Of the preceding six samples of Big seam ore the Hammond sample represents soft ore from the entire thickness of the seam, the Ishkooda sample is self-fluxing, and the other four are siliceous hard ores. The two from the Spaulding mine are comparatively

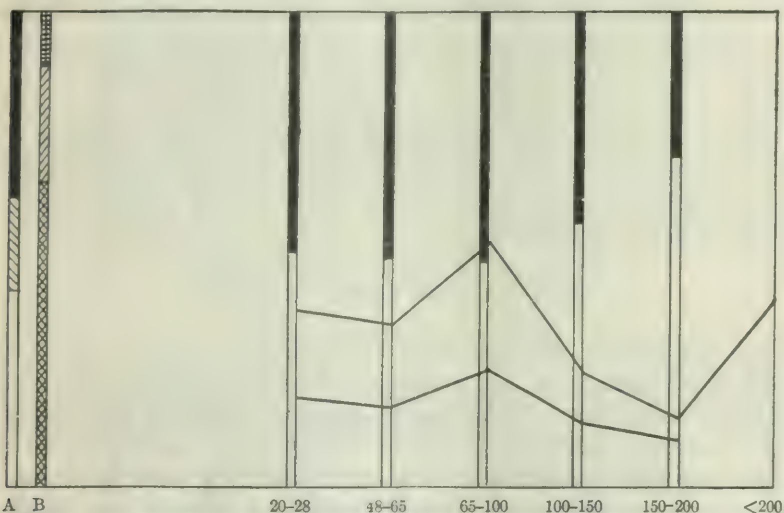

FIGURE 8.—Results of tests of sample 6 under 35 mesh.

good for ores of that type, but the two from the Ruffner mine are low in iron and high in silica and can not be utilized in their present condition.

Concentration of the self-fluxing Ishkooda ore yielded a self-fluxing concentrate more than 10 per cent higher in iron and 3 per cent lower in silica than the original ore. Though the product is more valuable, concentration would hardly be justified because the crude ore is itself marketable.

The Spaulding ores represent those that are too siliceous to work except when the iron market is strong. The average of the two samples is 36.3 per cent Fe and 17.8 per cent SiO_2, and in one sample the lime content is 11.1. The concentrates average 46.3 per cent Fe and 9.4 per cent SiO_2, and the lime content of one sample is 8.5. In other words, concentration of a decidedly siliceous ore yielded a con-

centrate carrying 10 per cent more iron, 8.4 per cent less silica, and nearly self-fluxing. Addition of the slimes to the concentrates makes a product averaging 45.8 per cent Fe and 9.5 per cent SiO_2, a reduction of only 0.5 per cent Fe and an increase of 0.1 SiO_2, with an increase of iron recovery from 84.7 to 94 per cent. Thus the concentration of the upper-bench Spaulding ore, which has been utilized only when the iron trade was most active, yielded a product better than the best of the crude ores of the district.

The soft Hammond ore, which in its crude state is too low in iron and high in silica to have any value, yielded a concentrate somewhat better than the average soft ore of the district, which according to Phillips[a] carries 50.80 per cent Fe and 18.50 per cent SiO_2.

Least promising are the results from the two samples of Ruffner ore. They average 28.8 per cent Fe and 30.9 per cent SiO_2, and the concentrates average 42 per cent Fe and 18.5 per cent SiO_2. In one sample the lime content fell from 10.2 in the crude ore to 6.9 per cent in the concentrates. The average of concentrates plus slimes is 40.5 per cent Fe and 17.1 per cent SiO_2, and the iron recovery is thereby increased from 67.6 per cent to 88 per cent. Either product is below the limits of marketable ore.

BIG SEAM ORE FROM FRANK WHITE MINE.

Four samples of soft ore were taken from the open cut of the Frank White mine, on the summit of Red Mountain, at the south end of Birmingham. An incline leads from this open cut, which is several hundred feet long, to the railroad tracks. At the top of the incline the entire thickness, 18 feet, of the Big seam is exposed. Only the upper 6 feet has been worked, and from it two samples were taken, one from each side of the incline. A third sample was taken at the incline, from the middle 6 feet of the bed, and a fourth at the same place from the lowest 6 feet, which is much finer grained than the rest of the bed, as indicated by the screen-analysis curves (figs. 12 and 13). The ore from the middle 6 feet is similar in appearance to that from the upper, but, as the analyses show, is much poorer, being high in silica and low in iron for a soft ore. Because of the three divisions of the bed, and the samples being taken at the outcrop, they are considered apart from the rest of the Big seam samples.

SAMPLE 7. FRANK WHITE MINE.

Sample 7 represents the upper 6 feet of the Big seam in the part of the open cut south of the incline.

[a] Phillips, W. B., Iron making in Alabama, 3d ed.: Alabama Geological Survey, 1912, p. 30.

SAMPLE 8. FRANK WHITE MINE.

Sample 8 represents the upper 6 feet of the Big seam in the part of the open cut north of the incline.

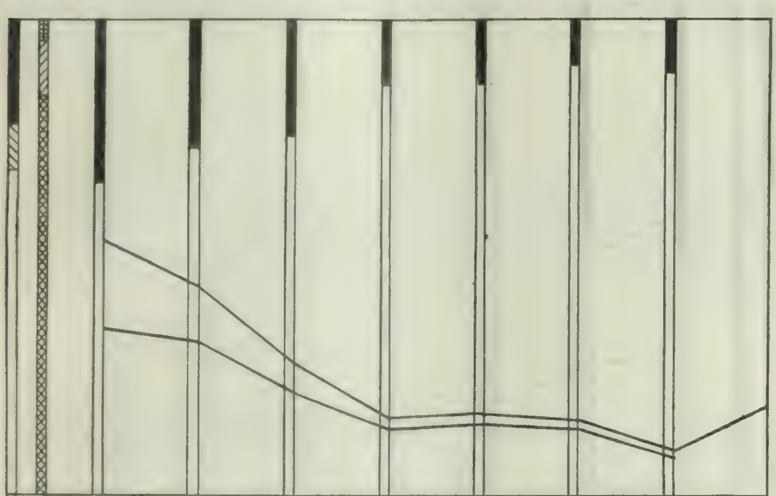

FIGURE 9.—Results of tests of sample 7.

SAMPLE 9. FRANK WHITE MINE.

Sample 9 was taken from the middle 6 feet of the Big seam, where it is cut by the incline at the top of the ridge.

FIGURE 10.—Results of tests of sample 8.

SAMPLE 10. FRANK WHITE MINE.

Sample 10 was taken from the lowest 6 feet of the Big seam, where it is cut by the incline at the top of the ridge.

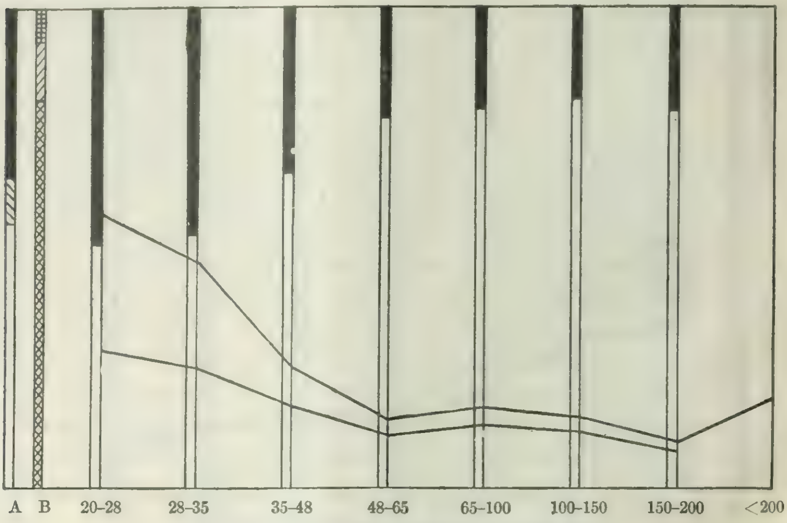

FIGURE 11.—Results of tests of sample 9.

No analyses were made of the products of this separation; but, as the ore was much finer grained than that from the overlying part

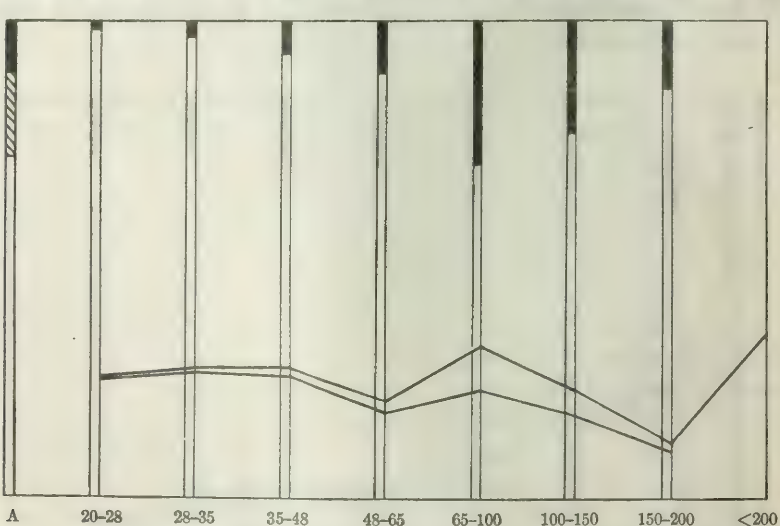

FIGURE 12.—Results of tests of sample 10.

of the bed, another portion of the sample was crushed to pass 35 mesh, and subjected to separation tests. The results are given on page 22.

As no analyses were made of the 20-mesh separation products, the composition of the products can not be compared. In the 35-mesh test the percentage of concentrates was reduced 8 per cent and percentage of tailings increased 6.4 per cent. Probably the concentrate was a little higher in grade and the slimes, on account of silica being crushed, a little lower. The screen-analysis curves show the same characteristics.

COMMENTS ON TESTS OF ORE FROM FRANK WHITE MINE.

In the separation tests the upper 6 feet of soft ore, averaging, in the two samples, 44.6 per cent Fe and 25.3 per cent SiO_2, gave a concentrate averaging 53 per cent Fe and 12.9 per cent SiO_2, with

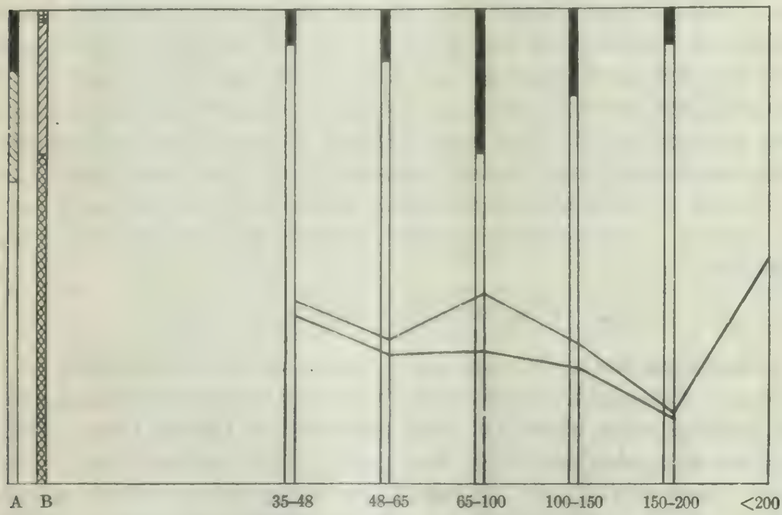

FIGURE 13.—Results of tests of sample 10 under 35 mesh.

a ratio of concentration of 1.42; adding the slimes to the concentrates gives a product averaging 53 per cent Fe and 12.9 per cent SiO_2, with a concentration ratio of 1.25 and an increase in iron recovery from 84.5 to 96.2 per cent. Adding the slimes to the concentrates materially increases the iron recovery without lowering the grade of the concentrate. The iron content of the crude ore is about 6 per cent below the average for the soft ore of the district and about 7 per cent higher than the average in silica, and the ore can be utilized only when the iron trade is active. The tests produced from it a product equaling in grade the best ores obtainable in the district.

The middle 6 feet of the Big seam is too low grade to be workable. The concentrates are poorer than the average soft ore of the district, and hence concentration by the method described would not be feasible for this part of the bed.

The composition of the lowest 6 feet of the bed is almost identical with that of the upper 6 feet, but the concentrates were no better than those from the middle 6 feet. The slimes from the lowest 6 feet are of much higher grade, however, and adding them to the concentrate gives a product slightly better than the average soft ore. The results are much poorer than those obtained with the upper 6 feet, and indicate that concentration of such ore is not practicable with the method used. The much finer grain of this ore, which prevents the silica from being separated to the same degree, accounts for the difference, although the ore was crushed to pass 35 mesh as against 20 mesh for ore from the upper 6 feet.

Averaging the analyses gives 42.2 per cent Fe and 30.5 per cent SiO_2 for the total thickness of the seam. Concentrates from it would carry 50.9 per cent Fe and 17.2 per cent SiO_2, with a ratio of concentration of 1.60 and an iron recovery of 78.2 per cent. Adding the slimes to the concentrate gives a product averaging 51.1 per cent Fe and 16.8 per cent SiO_2, with a ratio of concentration of 1.31 and an iron recovery of 95.5 per cent. Hence it seems that concentration of the entire bed, with an iron recovery of 95.5 per cent, would yield a product considerably better than the average of the soft ore of the district. Concentration would, therefore, make the entire seam workable.

ORE FROM THE LOWER BENCH, BIG SEAM.

There were tested 23 samples of ore from the lower bench of the Big seam from mines between Bessemer and Graces Gap and one from the Ruffner mine, about 10 miles northeast of Graces Gap. The 23 samples were obtained from that part of the district in which mining is most active, and, consequently, beneficiation of the siliceous ores is of immediate importance. Hence these ores have received more attention in this investigation than other ores and other parts of the district.

SAMPLE 11. RUFFNER MINE.

Sample 11 represents the upper 8 feet of the lower unworkable part (11 feet thick) and was taken in 2 left heading, 30 feet from the slope. It has the same fine grain as ore from the upper part of the seam, this feature being clearly shown by the screen-analysis curves (figs. 14 and 15).

Because of the ore being fine grained, the separation products were not analyzed, but another part of the sample was crushed to pass 35 mesh and tested, with the results given on page 22.

As the 20-mesh products were not analyzed, their composition can not be compared. The 35-mesh size yielded 8.5 per cent less

concentrates, 5.6 per cent more slimes, and 2.9 per cent more tailings. This doubtless means that the concentrates of the 35-mesh size are

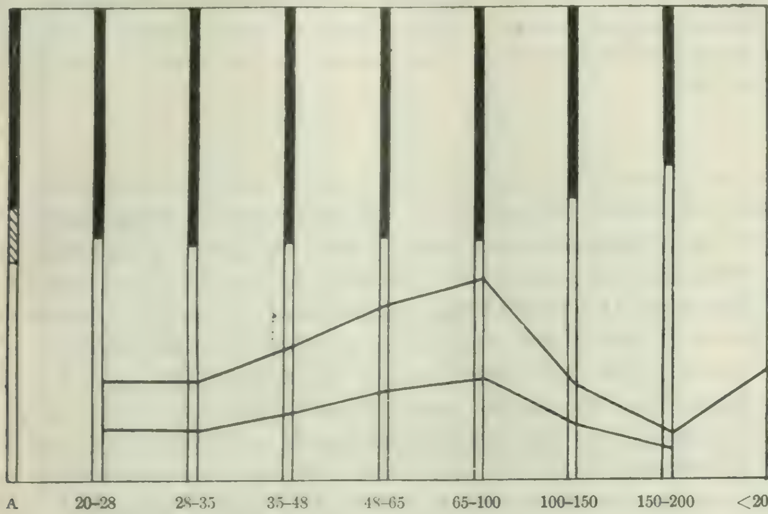

FIGURE 14.—Results of tests of sample 11.

appreciably better but the slimes are poorer than those of the 20-mesh size. The crude ore is of slightly lower grade than the two tested samples of crude ore from the upper part of the seam, yet the con-

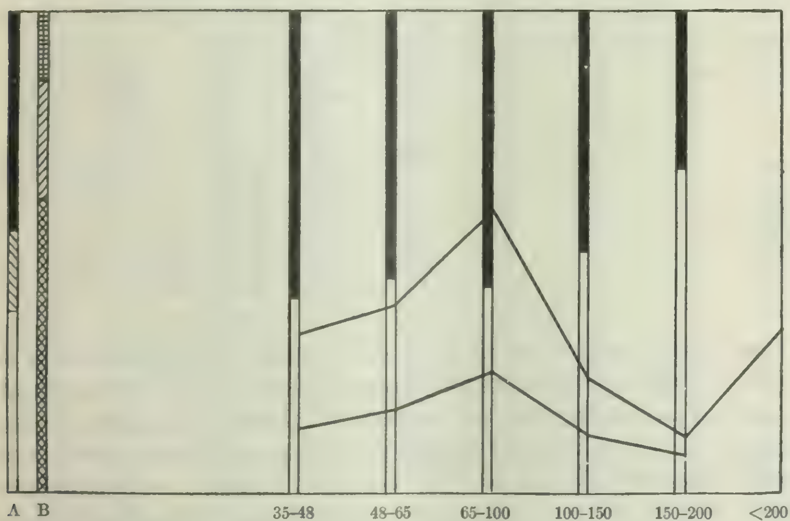

FIGURE 15.—Results of tests of sample 11 under 35 mesh.

centrate obtained runs 2 per cent higher in iron and nearly 1 per cent lower in silica than the average of that obtained from the other two samples; and the composition of concentrates plus slimes runs 2.2

per cent higher in iron and 1.3 per cent lower in silica than for the upper ores. As in the tests of the upper ore, however, the grade of the products is too low to make concentration attractive. The results would indicate that, if the Ruffner ore is to be concentrated, the entire bed will yield as good results as the upper 7 feet worked in the past.

SAMPLE 12, SPAULDING MINE.

In the Spaulding mine the Big seam is about 22 feet thick. No parting separates the seam into an upper and a lower bench, the upper more calcareous and less siliceous ore grading into the lower less calcareous and more siliceous ore. When the mine was active only the upper 11 feet of the seam was mined. Sample 12 represented the lower 11 feet of the seam and was taken in 1 left heading, cross left (a cross left is a branch to the left from a left main heading, and hence cuts well into the lower bench), 700 feet from the slope.

The concentrates and tailings from each mesh size were analyzed, and from the analyses the composition of the concentrates and tailings, as given on page 23, was calculated. The composition of the crude ore of each mesh size and the percentages of iron that went into the concentrates and tailings were calculated. The results are shown in the table below:

Composition of concentrates and tailings by mesh sizes.

Size of mesh.	Concentrates.		Tailings.		Crude.		Total iron in—	
	Fe.	SiO_2.	Fe.	SiO_2.	Fe.	SiO_2.	Concentrates.	Tailings.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
20 to 28	42.2	15.6	8.6	75.5	29.4	38.5	88.8	11.2
28 to 35	44.1	12.7	8.6	73.1	32.2	33.0	91.0	9.0
35 to 48	45.0	10.8	8.9	64.5	36.1	24.0	93.9	6.1
48 to 65	47.0	9.2	9.3	54.2	38.5	19.3	94.6	5.4
65 to 100	48.6	8.9	8.5	54.0	39.9	18.7	95.4	4.6
100 to 150	53.1	7.5	8.9	48.7	43.5	16.4	95.6	4.4
150 to 200	52.4	9.6	14.9	42.4	45.1	16.0	93.5	6.5
200					46.1	14.0		

The 20 to 28 and 28 to 35 mesh sizes are of lower grade than the original crude ore, whereas the finer sizes are all of higher grade, the quality improving with the fineness. If the 20 to 28 mesh size were rejected, the concentrate obtained from the remainder would average 46.7 per cent Fe and 10.6 per cent SiO_2, with a ratio of concentration of 2.07 and an iron recovery of 59.9 per cent. This product would run 1.2 per cent higher in iron and 1.3 per cent lower in silica, but the decrease in the iron recovery would be 23.2 per cent. Hence rejection of that size would not be warranted.

SAMPLE 13. SPAULDING MINE.

Sample 13 represents the upper 6 feet of the lower bench in 3 left heading, at the breast.

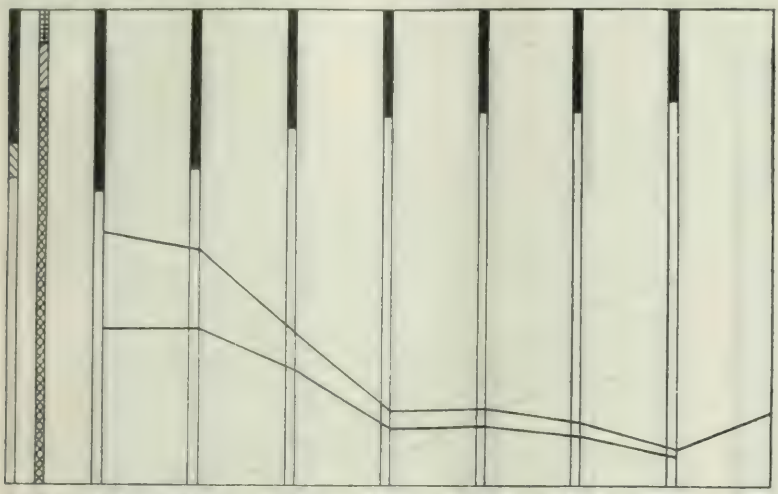

FIGURE 16.—Results of tests of sample 12.

SAMPLE 14. SPAULDING MINE.

Sample 14 was taken from the upper 4 feet of the lower bench of the Big seam in 5 left heading, 1,600 feet from the slope.

FIGURE 17.—Results of tests of sample 13.

Another part of the sample was crushed to pass 35 mesh and subjected to separation tests, with the results given on page 24. Only

the concentrates were analyzed, they contained 45.3 per cent Fe and 13.0 per cent SiO_2, the ratio of concentration being 1.90 and the iron recovery 67.7 per cent. Compared with the 20-mesh test these concentrates have only 0.2 per cent more iron, and only 0.5 per cent less

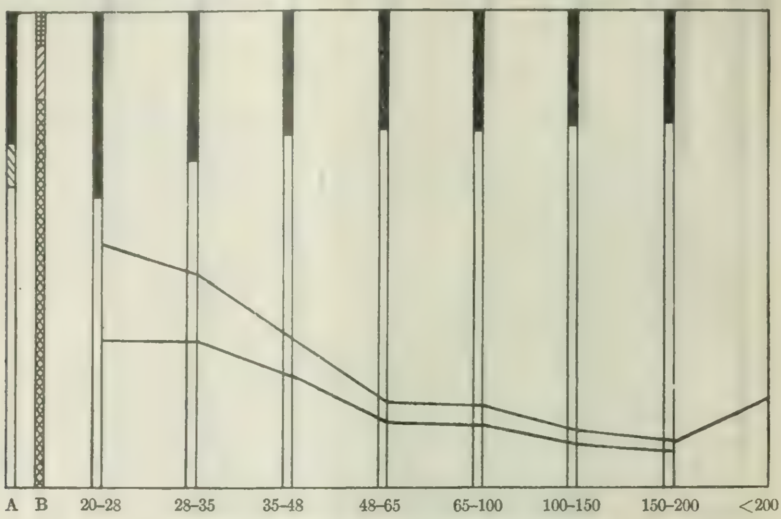

FIGURE 18.—Results of tests of sample 14.

silica, although the iron recovery is 13.7 per cent less. Such results would not justify the finer grinding. The amount of tailing is nearly the same for both 20 and 35 mesh ore, so that the lower percentage of concentrates is due almost entirely to the higher percentage of slimes.

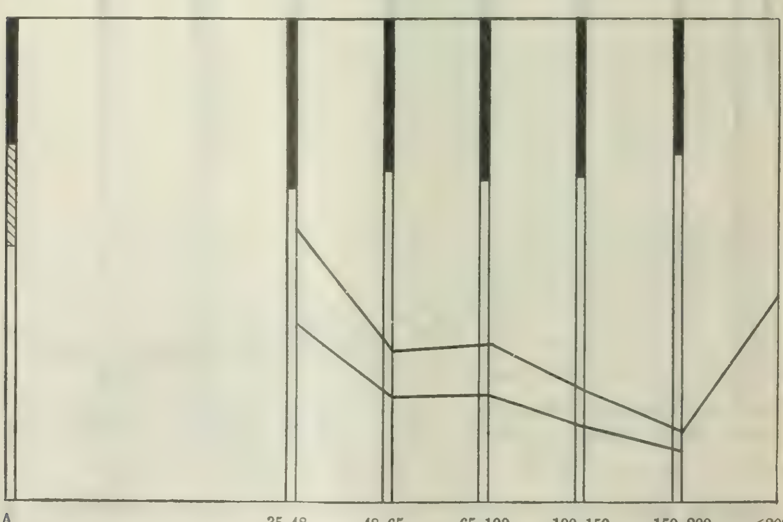

FIGURE 19.—Results of tests of sample 14 under 35 mesh.

SAMPLE 15. SPAULDING MINE.

Sample 15 was taken from the upper 3 feet of the lower bench of the Big seam in 6 left heading, at the breast of the drift.

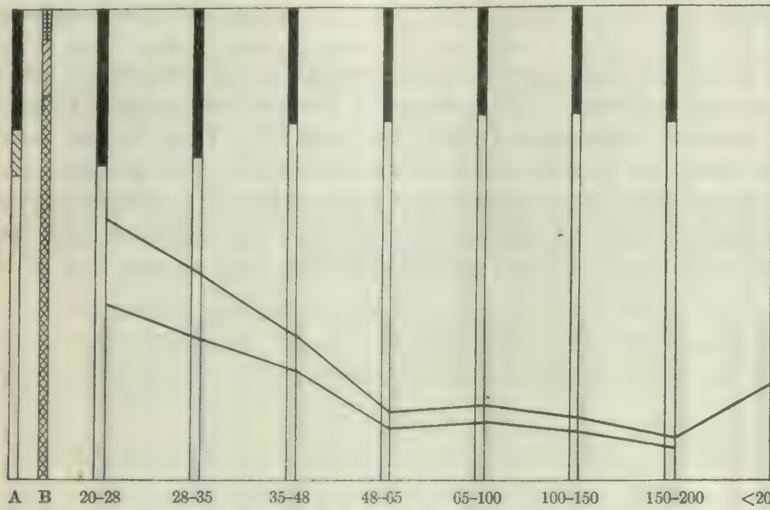

FIGURE 20.—Results of tests of sample 15.

SAMPLE 16. SPAULDING MINE.

Sample 16 was taken from the 3 feet of ore immediately below the workable ore, in 10 left heading, at the breast.

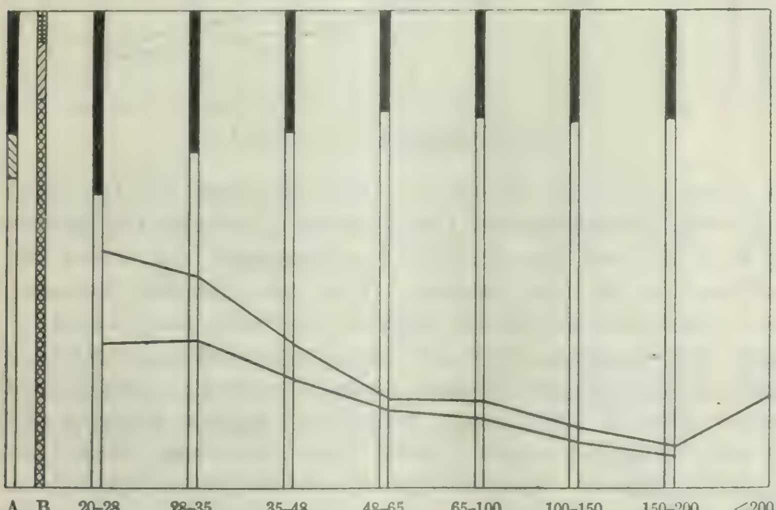

FIGURE 21.—Results of tests of sample 16.

SAMPLE 17. SPAULDING MINE.

Sample 17 was taken from the upper 8 feet of the lower bench of the Big seam in 6 right heading, 600 feet from the slope.

COMMENTS ON TESTS OF LOWER BENCH BIG SEAM ORE FROM THE SPAULDING MINE.

The results of the tests of the preceding six samples of ore are strikingly uniform. The average of the results obtained from the six samples is given in Table 1 on page 38. They deviate only a little from the results obtained with the individual samples, hence the Spaulding lower bench ore is presumably of uniform character throughout, and the results obtained may be regarded with more than usual confidence as representing what may be expected of this

FIGURE 22.—Results of tests of sample 17.

ore under large-scale treatment. The slimes are so little lower in grade than the concentrates that in order to increase the iron recovery 11.4 per cent the mixture of concentrates plus slimes can be considered as the final product. Then concentration increases the iron 9.5 per cent, reduces the silica 13.7 per cent, and, judged by the single determination, leaves the percentage of lime practically unchanged, the net result being a decided increase in quality, with a concentration of about 4 tons into 3 and an iron recovery of 93.3 per cent. Such a product is better than the average washed brown ore of the district. Burchard[a] gives 23 analyses of washed brown

[a] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Ala.: U. S. Geol. Survey Bull. 400, 1910, p. 169.

ore from the Woodstock and Champion areas, which average 45 per cent Fe, 14.6 per cent SiO_2, 4 per cent Al_2O_3, and 0.74 per cent Mn. The Spaulding concentrate runs 0.6 per cent higher in iron and 1.5 per cent lower in silica and its lime content more than counterbalances the manganese content of the brown ore. According to the results, concentration of the lower bench Spaulding ore should produce a product that can easily compete with the brown ores of the district.

SAMPLE 18. ISHKOODA MINE.

The upper bench in the Ishkooda mine is about 7 feet thick. A mere parting along the bedding plane with only here and there a thin layer of shale separates it from the lower bench. In working this bench about 3 feet and sometimes as much as 5 feet of the lower bench ore is also taken. From 7 to 10 feet of ore is left beneath and sample 18 was taken from it in 18 left heading, 200 feet from the slope.

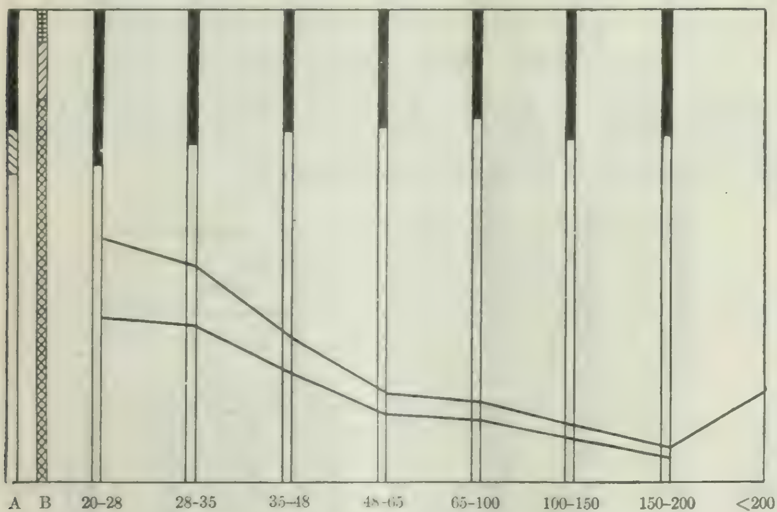

FIGURE 23.—Results of tests of sample 18.

SAMPLE 19. ISHKOODA MINE.

Sample 19 was taken from the upper 4 feet of the lower bench of the Big seam at the same place as sample 18 and represents lower bench ore that is mined with upper bench ore.

SAMPLE 20. ISHKOODA MINE.

Sample 20 was taken in 15 right heading, 500 feet from the slope, and represents the lower bench 8 to 10 feet below the parting.

The concentrates and tailings of each mesh size were analyzed separately and the composition of the concentrates and tailings for

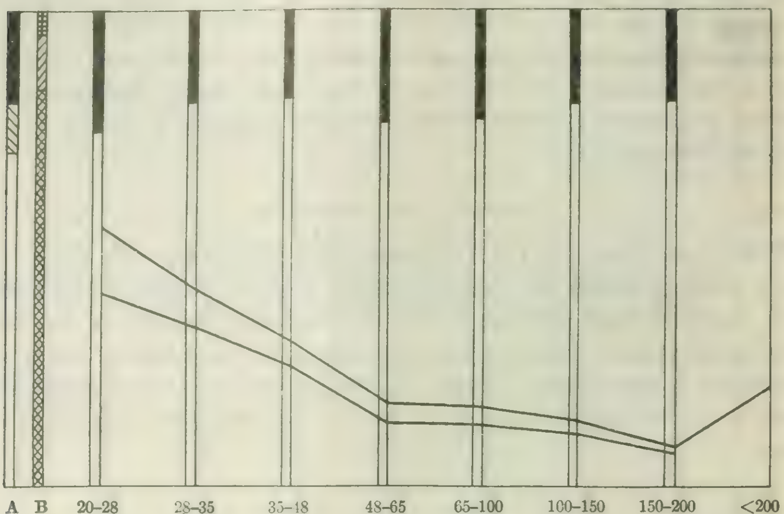

FIGURE 24.—Results of tests of sample 19.

the entire sample, as given in Table 1 on page 26, was calculated from these. The table below shows these analyses and the calculated composition of the crude of each mesh size.

Composition of concentrates and tailing by mesh sizes.

Size of mesh.	Concentrates.		Tailings.		Crude.		Total iron in—	
	Fe.	SiO_2.	Fe.	SiO_2.	Fe.	SiO_2.	Concentrates.	Tailings.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
20 to 28	43.5	19.3	8.7	68.5	28.8	40.1	87.3	12.7
28 to 35	37.2	21.7	9.1	63.3	29.6	33.1	91.6	8.4
35 to 48	42.2	12.4	8.7	51.8	31.8	24.7	91.5	8.5
48 to 65	43.3	10.4	8.1	41.6	32.4	20.1	92.3	7.7
65 to 100	46.6	9.2	8.0	36.8	33.9	18.3	92.2	7.8
100 to 150	47.9	9.7	8.9	33.3	36.3	16.7	92.7	7.3
150 to 200	50.7	8.6	13.1	29.3	43.3	12.7	94.0	6.0
200	....	....	....	....	39.8	12.4	....	....

The 20 to 28 and 28 to 35 mesh sizes are of lower grade than the original ore, whereas all smaller sizes of the crude are of higher grade, the quality increasing with the fineness, except that the 150 to 200 mesh size contains more iron than the slimes, and is higher in iron and lower in silica than the concentrates themselves. Hence, everything smaller than 150-mesh might have been added directly to the final product.

Another part of the same sample was crushed to pass 35-mesh and subjected to separation tests, with the results given on page 26. By

analysis these concentrates contained 42.1 per cent Fe and 13.3 per cent SiO_2, the silica being nearly 3 per cent lower than in the con-

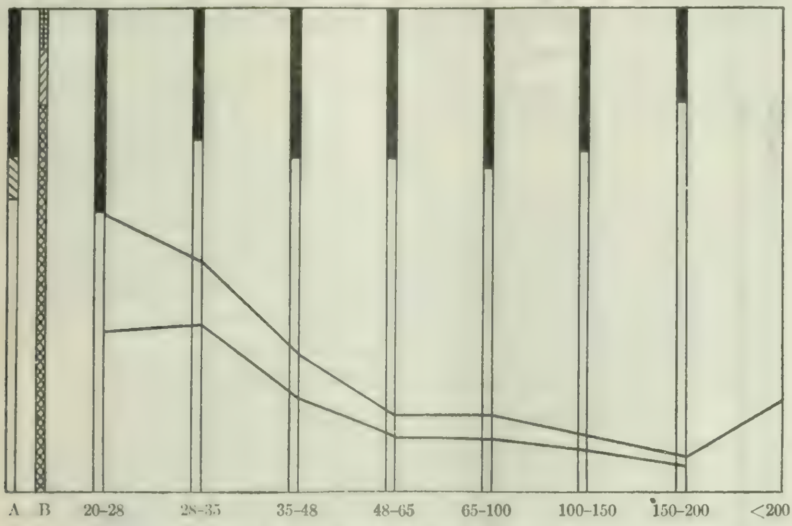

FIGURE 25.—Results of tests of sample 20.

centrates of the 20-mesh test. Compared with that test the ratio of concentration is 2.10 instead of 1.66, and the iron recovery 61.9 as against 80 per cent. Finer crushing increased the proportion of

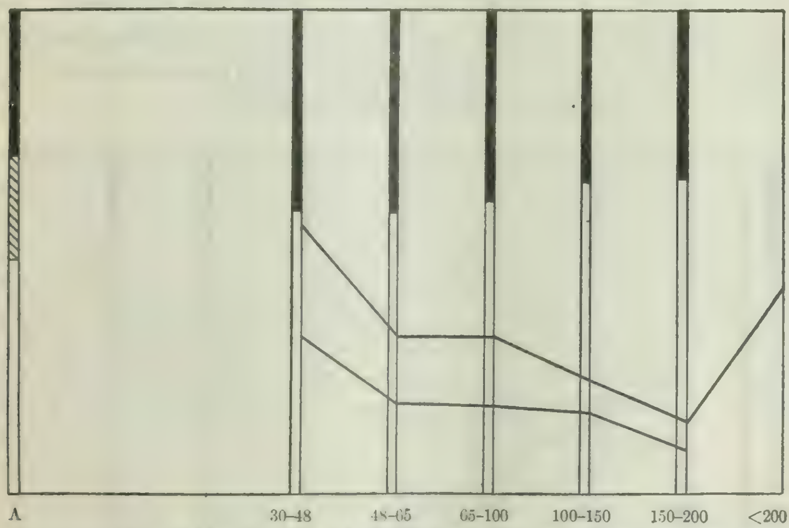

FIGURE 26.—Results of tests of sample 20 under 35 mesh.

tailings only a little more than 1 per cent, and the decrease of concentrates, 12.8 per cent, is offset by the larger proportion of slimes. Adding the slimes to the concentrates yields a final product that would probably differ little from the corresponding product of the 20-mesh test.

SAMPLE 21. ISHKOODA MINE.

Sample 21 was taken in 6 right heading, near the manway. Here the parting is a 1 to 2 inch layer of shale, and the sample was taken from the 3½ feet of ore just under it.

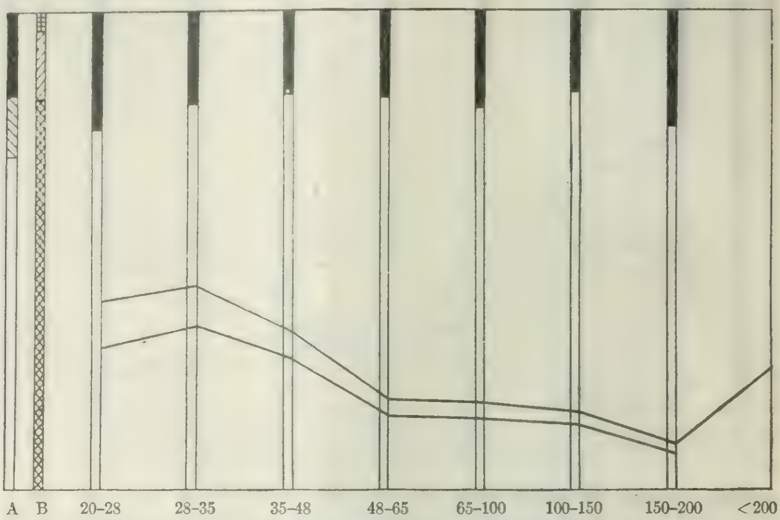

FIGURE 27.—Results of tests of sample 21.

SAMPLE 22. ISHKOODA MINE.

Sample 22 was taken from the upper 7 feet of the lower bench in 10 right heading, 200 feet from the slope. Here the parting is merely a break in the bedding, no shale being present.

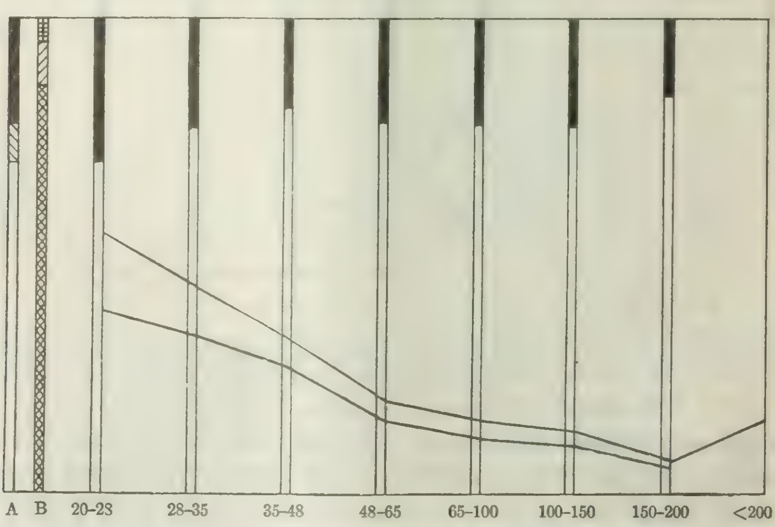

FIGURE 28.—Results of tests of sample 22.

COMMENTS ON TESTS OF ORE FROM LOWER BENCH IN ISHKOODA MINE.

Compared with the Spaulding ore, the five samples show considerable variation, largely because samples 20 and 21 represent only the less siliceous part of the lower bench ore that is taken out with the upper bench in mining. In consequence the averages of the five samples of Ishkooda ore, on page 37, are somewhat better than the probable average of the whole bench.

The composition of the slimes is so nearly like that of the concentrates that only a final product of slimes plus concentrates need be considered, this product being of the same grade and the iron recovery being higher. This product is 8.5 per cent higher in iron and 13.3 per cent lower in silica than the original ore and has about the same lime content according to the one determination. Compared with the average of the brown ores of the district (p. 76), this product runs 0.6 per cent higher in iron, 2.3 per cent lower in silica, and has a lime content of nearly 8 per cent to offset the manganese content of the brown ores. Judged by its composition, it can readily compete with them. As samples 19 and 21 represent only the best part of the lower bench, the results from samples 18, 20, and 22 were also averaged separately. The composition of the concentrates plus slimes averaged 44.0 per cent Fe and 13.6 per cent SiO_2, or 1 per cent less in iron and silica than the brown ores, and hence compares favorably with them. This result is obtained with a concentration of 4 tons into 3 and an iron recovery of 93.2 per cent.

SAMPLES FROM SONGO MINE.

In this mine the upper bench of the Big seam is 7½ to 9 feet thick and is separated from the lower bench by a 6 to 9 inch shale parting. The lower bench is about 12 feet thick, its upper 9 feet being relatively free from shale. At only one point, in 14 right heading, was the lowest 3 feet cut into, and there it consisted of intercalated shale and ore. Down to heading 23, the upper 9 feet of the lower bench has been cut into in the headings and the ore used by the Woodward Iron Co., which works this mine, in its own furnaces; but the quality is such that the ore can not be sold in the open market. Nearly all the ore mined is from above the shale parting.

SAMPLE 23, SONGO MINE.

Sample 23 was taken in 14 right heading, about 600 feet from the slope; at this point the entire lower bench is exposed, but on account of the lower 3 feet being shaly only the upper 9 feet were sampled.

SAMPLE 24. SONGO MINE.

Sample 24 represents the upper 6 feet of the lower bench in 12 left heading, 250 feet from the slope.

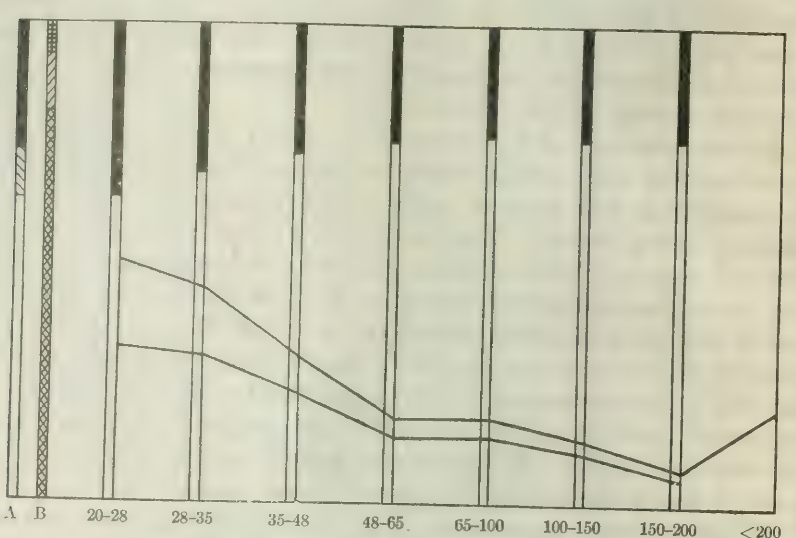

FIGURE 29.—Results of tests of sample 23.

SAMPLE 25. SONGO MINE.

Sample 25 was taken from the upper 9 feet of the lower bench in 15 left heading, 300 feet from the slope.

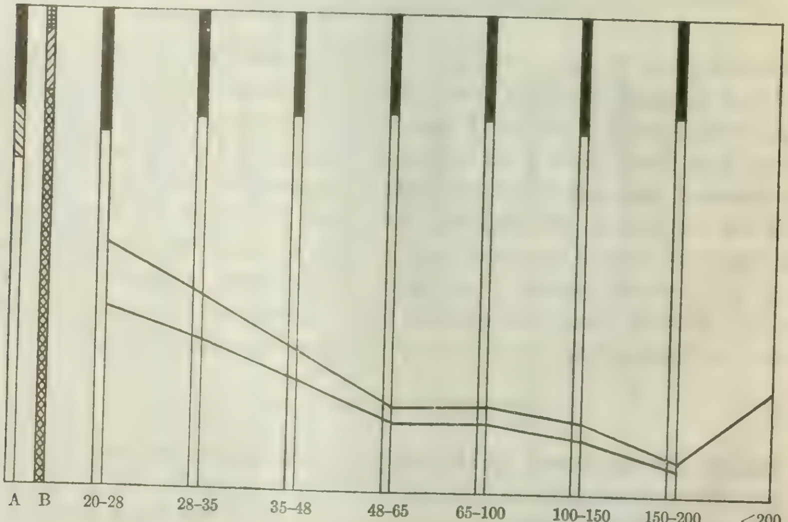

FIGURE 30.—Results of tests of sample 24.

SAMPLE 26. SONGO MINE.

Sample 26 was taken from the upper 9 feet of the lower bench of the Big seam in 18 right heading, 700 feet from the slope.

FIGURE 31.—Results of tests of sample 25.

SAMPLE 27. SONGO MINE.

Sample 27 was taken from the upper 9 feet of the lower bench in 19 left heading, 300 feet from the slope.

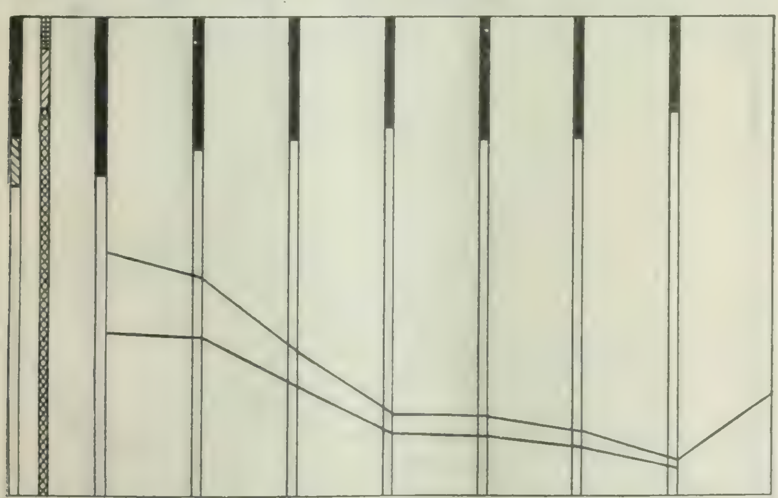

FIGURE 32.—Results of tests of sample 26.

Another portion of the sample was crushed to pass 35 mesh and subjected to separation tests, with the results given on page 29

The concentrates from this separation analyzed 45.7 per cent Fe and 11.0 per cent SiO_2, with a ratio of concentration of 1.79 and an iron recovery of 68.5 per cent. Finer crushing consequently produced a

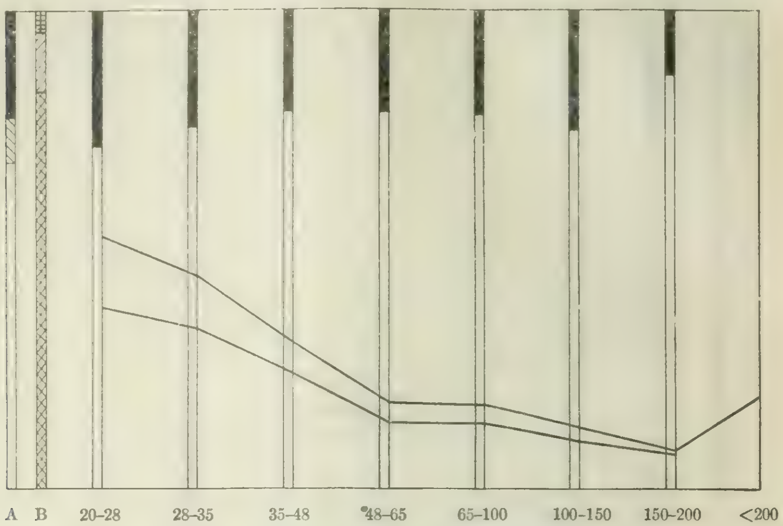

FIGURE 33.—Results of tests of sample 27.

concentrate 2.2 per cent higher in iron and lower in silica, but reduced the iron recovery from 83.2 to 68.5 per cent. The proportion of tailings was nearly the same in the two tests, and the slimes increased at the expense of the concentrates.

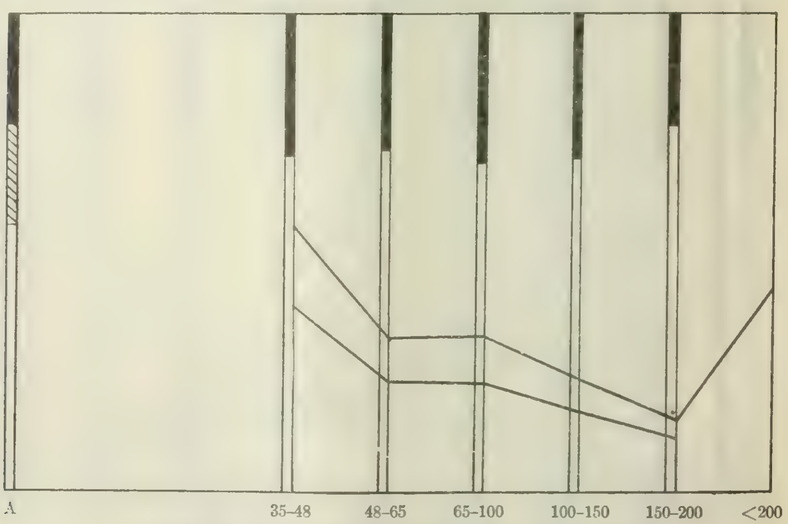

FIGURE 34.—Results of tests of sample 27 under 35 mesh.

SAMPLE 28. SONGO MINE.

Sample 28 was taken from the upper 8 feet of the lower bench of the Big seam in 23 left heading, 150 feet from the slope.

The concentrates and tailings of each mesh size were analyzed separately and the composition of the entire concentrates and tailings calculated from these analyses, which are given in the table below, with the calculated composition of the crude ore of each size.

Composition of concentrates and tailings by mesh sizes.

Size of mesh.	Concentrates.		Tailings.		Crude.		Total iron in—	
	Fe.	SiO_2.	Fe.	SiO_2.	Fe.	SiO_2.	Concentrates.	Tailings.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
20 to 28	41.5	15.4	8.3	65.3	31.9	29.9	92.4	7.6
28 to 35	43.8	12.4	8.2	62.6	35.2	24.4	94.4	5.6
35 to 48	44.6	11.1	8.1	54.7	37.3	19.9	95.6	4.4
48 to 65	54.8	9.9	8.3	46.8	38.3	17.3	95.7	4.3
65 to 100	49.5	8.8	7.9	43.1	38.7	16.2	95.6	4.4
100 to 150	53.0	7.7	6.9	42.9	43.0	15.2	96.6	3.4
150 to 200	54.4	8.1	7.1	41.8	45.3	14.6	97.0	3.0
200	....	....	....	....	47.4	11.7	....	....

Mesh sizes larger than 48 mesh are of lower grade and those smaller than 48 mesh are of higher grade than the original ore, each size being of higher grade than the preceding. Of the crude ore sizes only the slimes are better than the concentrates, but the crude 150 to 200 mesh ore runs better than the concentrate of the 20 to 28 mesh size.

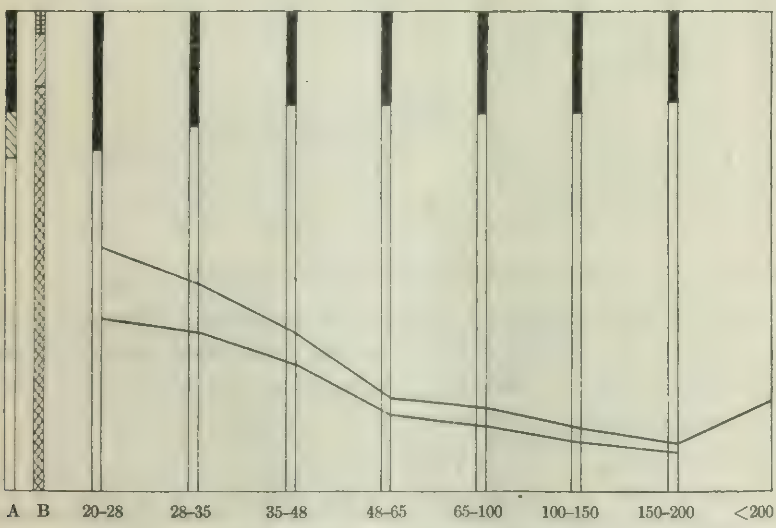

FIGURE 35.—Results of tests of sample 28.

COMMENTS OF TESTS OF ORE FROM SONGO MINE.

The six samples from the lower bench show a uniformity of composition almost equal to that of the Spaulding ore. Hence the bed at the points of sampling is of uniform grade chemically, and also, as

shown by the separation tests, physically. Such uniformity of character indicates that in actual practice there would probably be little deviation from these results. The average of the results obtained with the six samples is given in the table on page 38.

An average of several analyses supplied by Mr. A. H. Woodward of lower bench Songo ore is 39.5 per cent Fe, 20 per cent insoluble, and 10.4 per cent CaO. These figures indicate that the samples tested are representative of the ore. The slimes practically average the same as the concentrates, therefore, in view of the increased iron recovery, the final product may be considered as concentrates plus slimes. Such a product on the basis of 4 tons into 3, will give an iron recovery of 94.3 per cent, and be 6.6 per cent higher in iron, 8.7 per cent lower in silica, and nearly as high in lime as the crude ore.

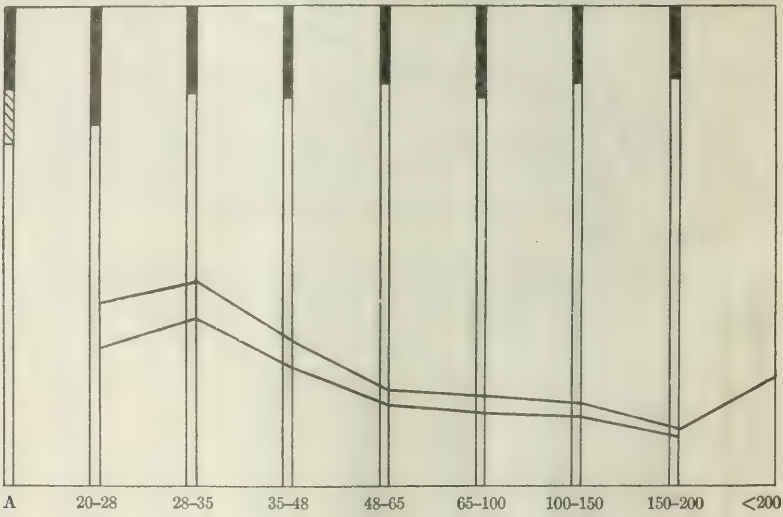

FIGURE 36.—Results of tests of sample 29.

Compared with the average of the brown ores of the district (p. 76), the product has the same iron content, 2 per cent less silica, and a high lime content to offset the manganese of the brown ores. On the basis of its chemical composition it can compete with those ores.

ORE FROM FOSSIL MINE.

SAMPLE 29. FOSSIL MINE.

In this mine the upper bench only of the Big seam is worked. Sample 29 represents the upper 4 feet of the lower bench, in 10 slope, 24 left heading, 100 feet from the slope.

Only the concentrates were analyzed, and they carried 48 per cent Fe and 12.1 per cent SiO_2. Another portion of the same sample was crushed to pass 35 mesh and subjected to separation tests, with the results given on page 30.

As the composition of the slimes is so much lower than that of the concentrates, adding the slimes to the concentrates would lower the grade of the final product. Yet as the iron recovery would be increased and the resulting product would still be slightly higher in iron and lower in silica than the average of the brown ores, the procedure would probably be found practicable. The 20 mesh concentrate is practically as good as the 35 mesh, and was obtained with a ratio of concentration of 1.40 as against 1.71, and an iron recovery of 86.2 per cent as against 71.1 per cent. There seems to be no advantage, therefore, in crushing this ore finer than 20 mesh. At least, 35 mesh is not fine enough to show an appreciable advantage.

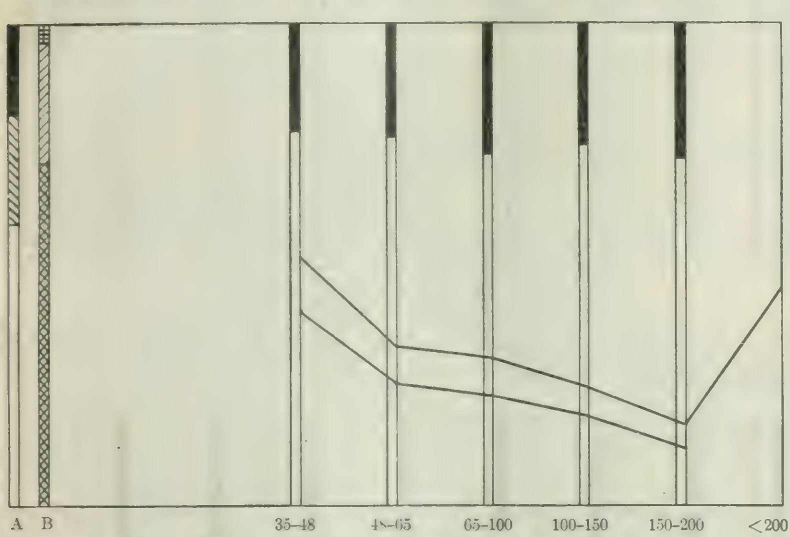

FIGURE 37.—Results of tests of sample 29 under 35 mesh.

SAMPLE 30. FOSSIL MINE.

Sample 30 was taken in 10 slope, 31 left heading, 125 feet from the slope. The lower bench here is a little more than 8 feet thick, and the sample represents the upper 8 feet of it.

SAMPLE 31. FOSSIL MINE.

Sample 31 was taken at 31 heading in the bottom of 10 slope. At that place the parting of the two benches comprises two ½-inch bands of shale, with a 4-inch layer of ore between. The lower bench is 9 feet thick, and the sample represents the entire thickness.

SAMPLE 32. FOSSIL MINE.

Sample 32 represents the entire thickness of the lower bench in 9½ slope, 23 left heading, 30 feet from the slope.

SAMPLE 33. FOSSIL MINE.

Sample 33 represents the whole thickness of the lower bench, on the north side of 9 slope between headings 47 and 49.

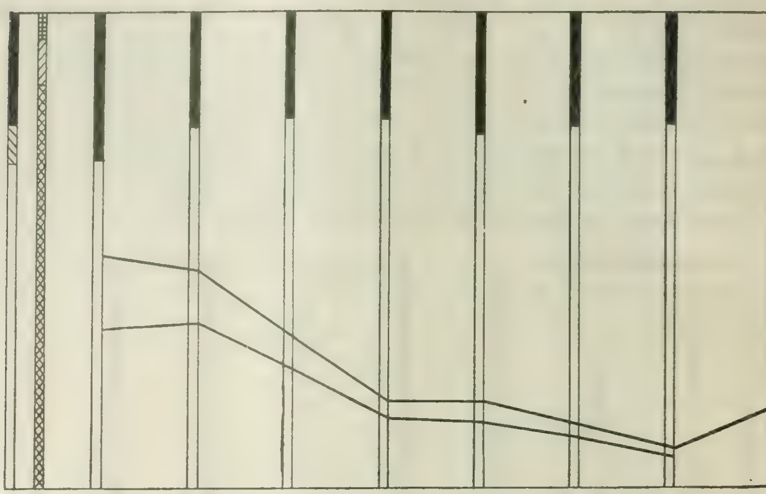

FIGURE 38.—Results of tests of sample 30.

The concentrates and tailings from the different mesh sizes were analyzed separately, and the composition of the concentrates and

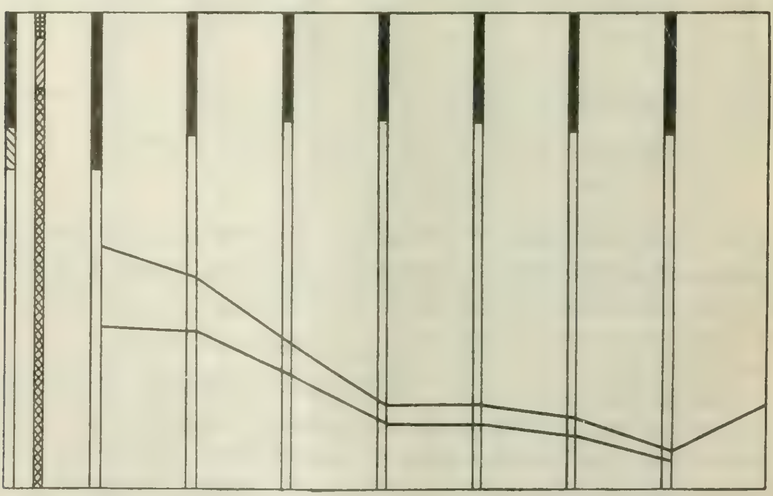

FIGURE 39.—Results of tests of sample 31.

tailings, as given on page 31, was calculated from these analyses. The calculated composition of the crude ore of each size and the per-

centage of iron that went into the concentrates and tailings of each are given in the accompanying table.

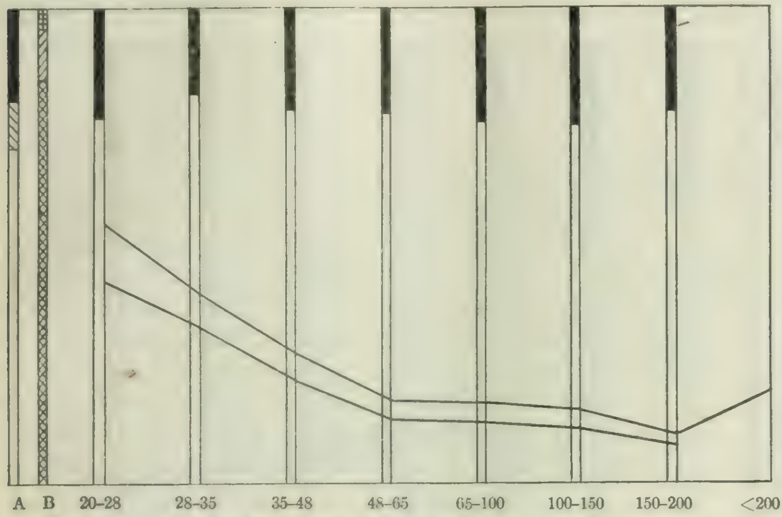

FIGURE 40. Results of tests of sample 32.

Composition of concentrates and tailings by mesh sizes.

Size of mesh.	Concentrates.		Tailings.		Crude.		Total iron in—	
	Fe.	SiO_2.	Fe.	SiO_2.	Fe.	SiO_2.	Concentrates.	Tailings.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
20 to 28	42.4	15.6	8.2	70.9	32.1	32.3	92.3	7.7
28 to 35	44.4	12.7	8.6	63.3	36.7	23.8	94.9	5.1
35 to 48	44.3	11.5	8.5	53.5	37.4	19.7	95.6	4.4
48 to 65	45.9	9.9	7.9	41.9	38.6	16.0	96.0	4.0
65 to 100	48.3	8.9	8.0	37.1	39.9	14.8	95.8	4.2
100 to 150	50.6	8.6	10.2	30.9	42.4	13.2	95.1	4.9
150 to 200	54.9	7.5	10.4	32.9	44.7	13.3	94.7	5.3
200					45.5	11.3		

In this sample the 35 to 48 mesh size has about the same grade as the crude ore, and the coarser sizes are poorer. The finer sizes improve in quality down to the fines. The slimes are the only size of the crude ore that runs better than the concentrates, but all the crude smaller than 100 mesh runs better than the concentrates of the 20 to 28 mesh size.

SAMPLE 34. FOSSIL MINE.

Sample 34 represents the entire lower bench in 8 slope between headings 48 and 50.

COMMENTS ON TESTS OF ORE FROM FOSSIL MINE.

As the results for sample 29 were obtained by crushing the ore to pass 35 mesh, and those for the rest of the samples by crushing to

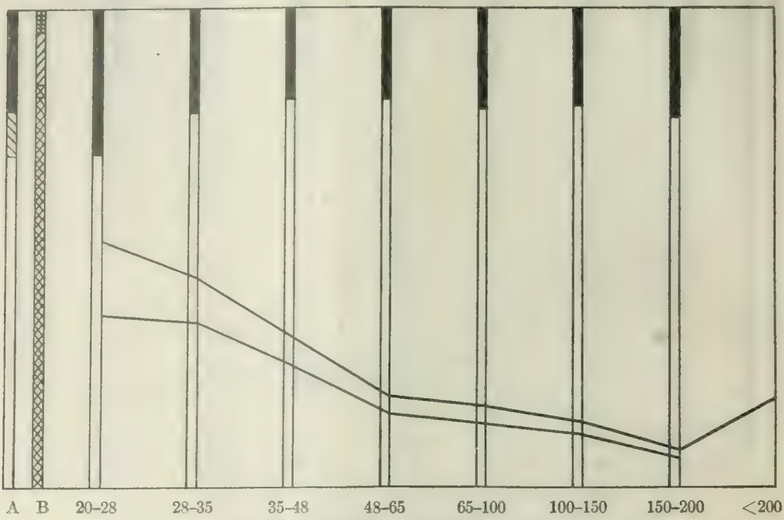

FIGURE 41.—Results of tests of sample 33.

pass 20 mesh, they are omitted in considering the average results (p. 39). The crude ore has the same composition as the other five

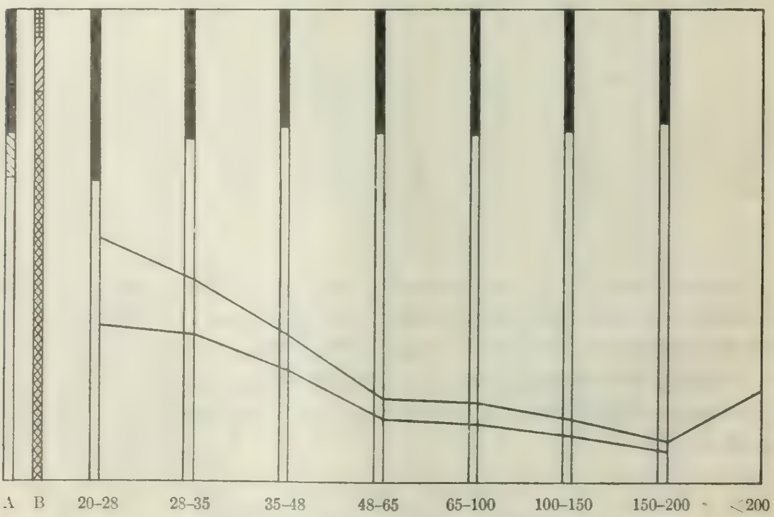

FIGURE 42.—Results of tests of sample 34.

samples, and the better products doubtless result from finer crushing, although the concentrate of the 20-mesh test runs a little higher than the concentrates from the rest of the samples.

An average of eight analyses of lower bench Fossil ore given by Burchard[a] is 37.3 per cent Fe, 20.2 per cent SiO_2, 3.3 per cent Al_2O_3, and 11.9 per cent CaO. This is very nearly the same as the average of samples 30 to 34, as given in Table 2 on page 39. The individual samples depart little from the average and show the uniformity of results that characterizes the separation tests. The ore is, therefore, shown to be quite uniform in chemical composition and physical character throughout the mine.

As the grade of the slimes is so little below that of the concentrates, it is advantageous to consider the final product as concentrates plus slimes. Then a concentration in the ratio of 4 tons into 3 yields an iron recovery of 94.8 per cent and a product 7.7 per cent higher in iron, 8.6 per cent lower in silica, and, on the basis of the one analysis, only 2 per cent lower in lime. Compared with the average of the washed brown ores of the district, such a concentrate would be 0.3 per cent richer in iron, 2.4 per cent lower in silica, and have an appreciable lime content to offset the value of the manganese in the brown ore. Hence, on the basis of its chemical composition it should be able to compete favorably with those ores.

SUMMARY OF COMMENTS ON TESTS OF LOWER BENCH BIG SEAM ORE.

On pages 50–71 are given the results of tests with 24 samples of ore from the lower bench of the Big seam. Sample 11 from the Ruffner mine represents very low grade ore and its wet concentration under present conditions does not seem justifiable.

The remaining 23 samples represent ore from different points in four important mines. Sample 29, from the Fossil mine, was crushed to 35 mesh, and the complete results are for that mesh size; as complete results for other samples were determined with the 20-mesh crushing, sample 29 is omitted from the discussion of the average results. Finer crushing of sample 29 had little effect, however, in improving the grade of the concentrate, as the 20-mesh concentrate contained only 0.1 per cent less iron and 0.4 per cent more silica than ore crushed to pass 35 mesh, and the iron recovery was 15 per cent higher. Hence there was no advantage in crushing this ore finer.

The average of the results obtained with the remaining 22 samples is given in the accompanying table. The column marked concentrates included the concentrates plus slimes.

[a] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Alabama, with chapters on the origin of the ores, by E. C. Eckel: U. S. Geol. Survey Bull. 400, 1910, pp. 83–84.

Average results of tests.

Mine.	Crude ore.			Concentrates.			Recovery of iron.	Ratio of concentration.
	Fe.	SiO_2.	CaO.	Fe.	SiO_2.	CaO.		
	P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	
Spaulding[a]	36.1	26.8	7.5	45.6	13.1	7.6	93.3	1.37
Ishkooda[b]	37.1	25.6	8.0	45.6	12.3	7.7	94.1	1.31
Songo[a]	38.4	21.2	10.5	45.0	12.5	9.5	94.3	1.30
Fossil[b]	37.6	20.8	9.6	45.3	12.2	7.6	94.8	1.30
Average of the four groups	37.3	23.6	8.9	45.4	12.5	8.1	94.1	1.32
Average composition of washed brown ores	....	....	....	45.0	14.6	....	....	....

[a] Average of six samples. [b] Average of five samples.

As the results from the 22 samples are decidedly uniform, the calculated average in the table may be safely taken as representing what one may expect from beneficiating these ores under the conditions of the experiments. The final product obtained by concentrating 4 tons of crude ore into 3, with an iron recovery of 94.1 per cent, runs 0.4 per cent higher in iron, and 2.1 per cent lower in silica than the brown ores, and has a considerable lime content to enhance its value.

ORE FROM THE IRONDALE SEAM.

The Irondale seam is of most value along the northeastern part of Red Mountain, from Pilot Knob southwest to a point about opposite Birmingham, a distance of about 10 miles. Farther southwest the bed becomes poorer, showing interstratified bands of low-grade ore and shale or losing its identity entirely. Burchard[a] says of the grade of the ore:

> Its soft ore, now nearly all mined out either by surface trenches or drifts, is the best of the district. Its hard ore is also of high grade and has hitherto been for the most part held in reserve, since ore could be produced from the thicker Big seam at a lower cost per unit of iron.

The seam lies only a few feet below the Big seam and has a thickness of 4 to 6 feet.

Three samples from this seam were tested—two from the Ruffner mine and the third from the Hammond mine—they being from the middle part of the belt within which the seam has its maximum value.

SAMPLE 35. RUFFNER MINE.

Sample 35 represents the entire thickness of the Irondale seam in 1 slope, 18 left heading, 650 feet from the slope. The bed here is 4 to 4½ feet thick.

[a] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Alabama, with chapters on the origin of the ores, by E. C. Eckel: U. S. Geol. Survey Bull. 400, 1910, p. 47.

SAMPLE 36. RUFFNER MINE.

Sample 36 represents the entire thickness of the Irondale seam in 1 slope, 22 right heading, 450 feet from the slope. The seam here is 4 feet thick.

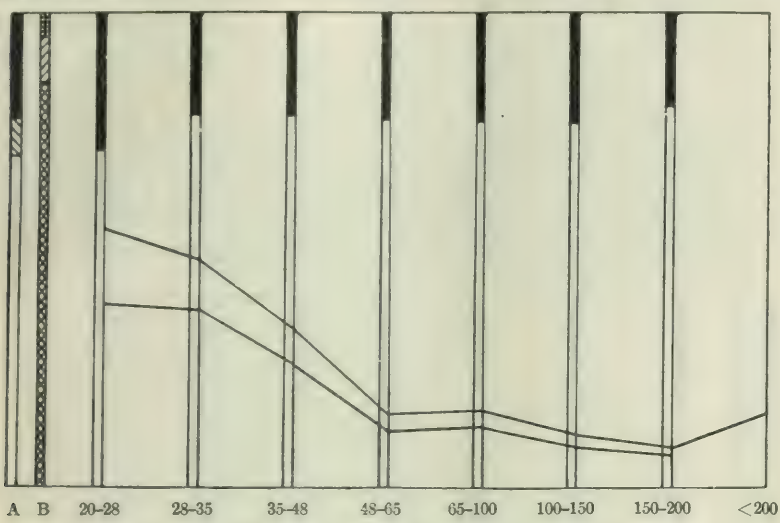

FIGURE 43.—Results of tests of sample 35.

SAMPLE 37. HAMMOND MINE.

Sample 37 was taken in the slope on the Irondale seam at the point where it is cut by the adit, that is, about 550 feet below the outcrop.

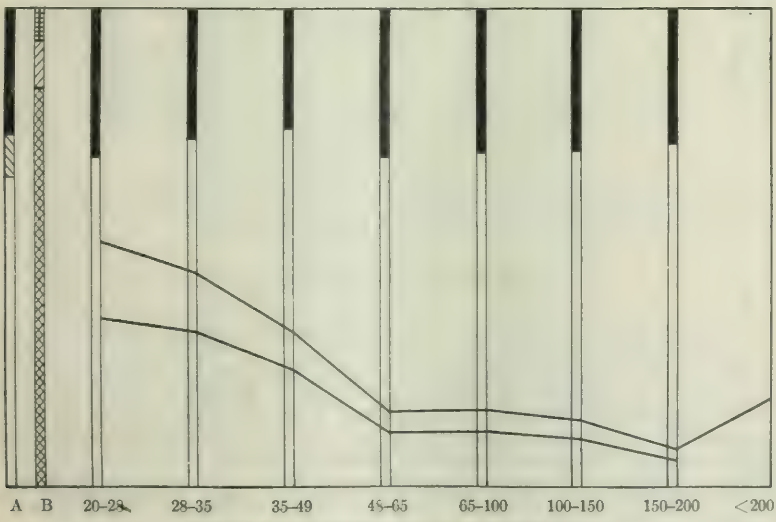

FIGURE 44.—Results of tests of sample 36.

The workable part of the bed was the lower 3½ feet, which was overlain by a thin layer of shale and 8 to 9 inches of low-grade ore discarded in mining.

COMMENTS ON TESTS OF ORE FROM IRONDALE SEAM.

Sample 37 is slightly better quality than the average ore of the lower bench of the Big seam. All three samples doubtless represent hard ore, and their average composition is 38 per cent Fe and 22.1 per cent SiO_2, or about the same as that of the lower bench Big seam ore. The concentrates average 45.1 per cent Fe and 14.2 per cent SiO_2, and hence are the same in iron, but 1.5 per cent higher in silica than the concentrates from the lower bench of the Big seam. A product composed of concentrates plus slimes show the same difference. However, the ratio of concentration averages a little less for the Irondale ores, so that the results obtained are practically the same as those obtained with the lower bench Big seam ores. Hence

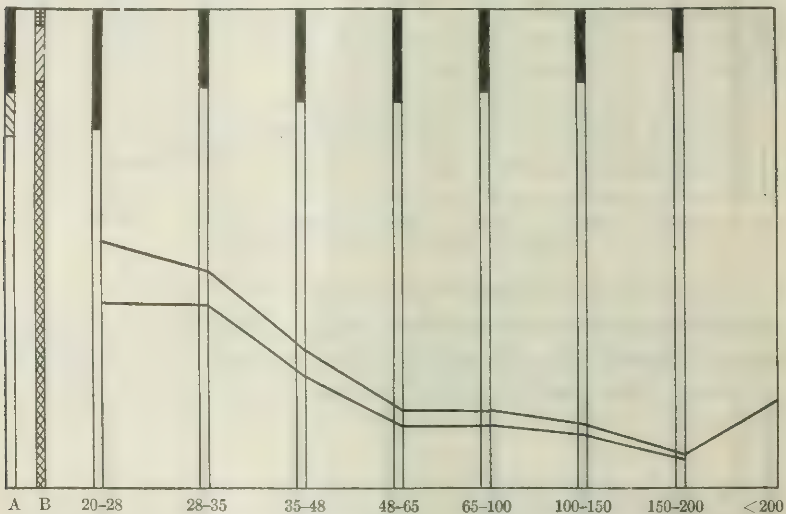

FIGURE 45.—Results of tests of sample 37.

the tests indicate that the Irondale ores are amenable to any treatment that might prove feasible for those ores.

ORE FROM THE IDA SEAM.

The following description of the Ida seam is given by Burchard:[a]

> This bed consists of 2 to 6 feet of rather siliceous ore associated with 14 to 16 feet of ferruginous sandstone. * * * Where worked, the bed is 3 to 5 feet thick, and soft ore only has been obtained from it in surface workings. Such ore carries 35 to 44 per cent of metallic iron, with a corresponding range in silica of 42 to 32 per cent.

Two samples from this seam were tested, one from the Ruffner mine and the other from the Hammond.

[a] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Alabama, with chapters on the origin of the ores, by E. C. Eckel: U. S. Geol. Survey Bull. 400, 1910, p. 46.

SAMPLE 38. RUFFNER MINE.

The outcrop of the Ida seam at the Ruffner mine is 5 feet thick, and the sample was taken at the face of an old open cut in what Mr. C. E. Barrett, the superintendent, called hard ore.

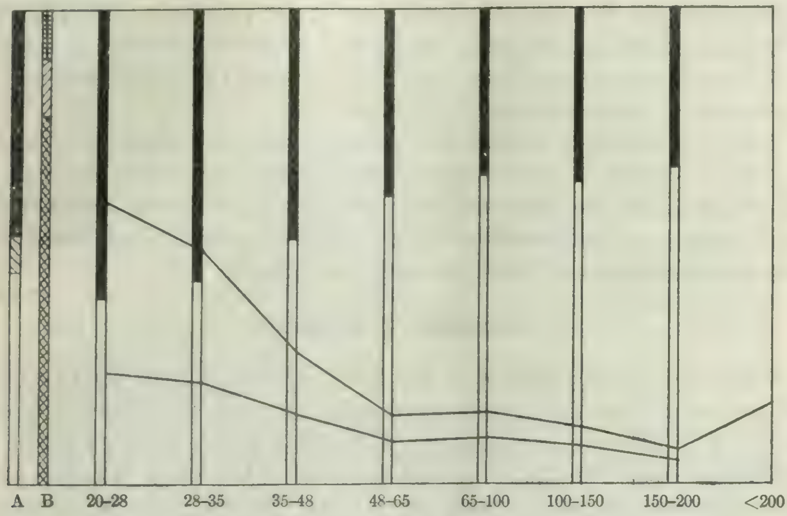

FIGURE 46.—Results of tests of sample 38.

SAMPLE 39. HAMMOND MINE.

Sample 39 was taken from the outcrop of the Ida seam along the face of the bed at the outside incline.

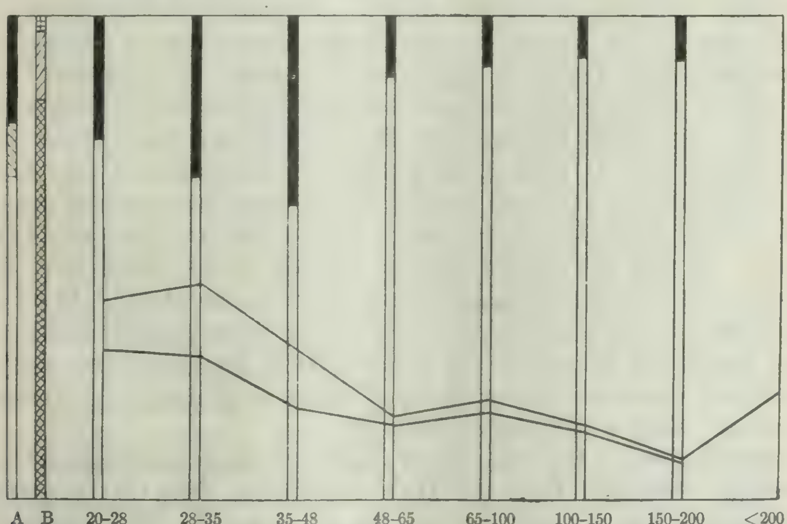

FIGURE 47.—Results of tests of sample 39.

COMMENTS ON TESTS OF ORE.

One sample represents hard ore, the other soft ore. The sample of soft ore is plainly finer grained than the sample of hard ore,

as is shown by the screen analysis curves (figs. 46 and 47). The sample of hard ore (sample 38) is the poorest ore tested, carrying less than 30 per cent. iron and more than 40 per cent silica, yet it yielded a concentrate carrying 47.5 per cent Fe and 14.7 per cent SiO_2, or just 2 per cent more iron and 2 per cent less silica than the average of the concentrates from the lower bench Big seam ore. This result would indicate that the siliceous Ida seam ores are as amenable to concentration as that ore.

The crude sample of soft ore (sample 39) runs high in iron, but its silica content is prohibitive. The concentrates from this sample show the high iron content obtained only in soft ore concentrates, and a silica content well within the allowable limit, and hence they can be advantageously used in the blast furnace.

RÉSUMÉ OF RESULTS.

There is a steady market in the Birmingham district for two types of iron ores—the calcareous hard red ores and the siliceous brown ores. The average composition of the hard red ores, as given by Phillips,[a] is 37 per cent Fe, 13.44 per cent SiO_2, 16.20 per cent CaO. The average of 23 samples of washed brown ore, as given by Burchard,[b] is 45 per cent Fe, 14.6 per cent SiO_2, 0.74 per cent Mn. Also there is available a limited quantity of workable soft ore, having an average composition, according to Phillips,[c] of 50.80 per cent Fe, 18.50 per cent SiO_2, and 1.20 per cent CaO. All of these ores average from 3 to 4 per cent Al_2O_3. As regards their smelting, the soft ores are in the same class as the brown ores, a higher iron content being offset by a higher silica content. The hard red ores grade by decrease of lime and increase of silica into siliceous ores, which, on account of their low iron content, can not compete with the brown ores, and hence are unworkable at present. Under favorable conditions, hard red ores of the average iron content can not be worked profitably if they carry about 8 per cent more silica than lime. By far the greater part of the red ore of the district falls below these requirements, and hence requires concentration to become available. As the concentrates obtained in the tests described herein are themselves siliceous and not self-fluxing, the brown ores serve as a basis for determining the value of the product obtained by concentration. Such a comparison follows:

Six samples of Big seam upper-bench ore taken underground were tested. Sample 4 from the Hammond mine, close to the surface, represents soft ore and includes the lower bench. Its concentrates

[a] Phillips, W. B., Iron making in Alabama, 3d ed.: Geol. Survey of Alabama, 1912, p. 35.

[b] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Alabama: U. S. Geol. Survey Bull. 400, 1910, p. 169.

[c] Phillips, W. B., work cited, p. 30.

run 51.7 per cent Fe and 18.4 per cent SiO_2; in other words, they equal the average workable soft ore, and their iron content is more than enough to carry the 4 per cent excess in silica as compared with the average brown ore. The crude ore is unworkable, with silica in excess of iron.

Sample 1 from the Ishkooda mine is a workable, self-fluxing ore and was tested in order to ascertain the results of concentration. The concentrate is self-fluxing and 10 per cent higher in iron.

Sample 2 and 3 from the Spaulding mine represent upper bench ores that are workable only when iron is in good demand. Their concentrates are higher in iron than the average brown ores and, being nearly self-fluxing, are superior to those ores.

Two samples from the Ruffner mine, samples 5 and 6, represent extremely poor ore, with silica in excess of iron, averaging 28.8 per cent Fe and 30.9 per cent SiO_2. The concentrates are of much better quality, averaging 40.5 per cent Fe and 17.1 per cent SiO_2, but are too poor to be marketable.

These experiments show that the unworkable upper bench hematites of the Big seam will yield a concentrate of greater value than the brown ores unless the grade of the crude hematites is very low.

Four samples of ore were taken from the outcrop of the Big seam at the Frank White open cut. Two of these, samples 7 and 8, represent the upper 6 feet of the seam (all that was worked) but are so much lower in iron and higher in silica than the average soft ore that this part of the bed can be worked only when the iron trade is unusually active. Concentration yielded a high-grade product, carrying 53 per cent Fe and 12.9 per cent SiO_2. The middle 6 feet, sample 9, is of very low grade, with 5 per cent more silica than iron, yet the concentrate is only a little poorer than the average soft ore mined. Sample 10, from the lower 6 feet, shows about the same composition as the ore from the upper 6 feet, but the concentrate was poorer, having about the composition of the average workable soft ore, probably because of the finer grain. The entire seam averages 42.2 per cent Fe and 30.5 per cent SiO_2, and the concentrates from it 50.9 per cent Fe and 17.2 per cent SiO_2. Therefore, concentration at this mine could make a product of slightly better grade than the average of the soft ores out of an 18-foot seam of ore, of which only the upper 6 feet can even be considered as available in its crude state.

Twenty-four samples of Big seam lower bench ore were tested, of which one, sample 11 from the Ruffner mine, represents an extremely low-grade ore from the northeastern part of the district. The others represent the lower bench in that part of the district, where the upper bench is worked extensively and the lower bench is left unmined.

The sample of lower bench Ruffner ore is slightly poorer than the two samples of the upper bench ore tested, but the concentrate runs a little better. However, the concentrate is below the grade of the brown ores, and hence concentration would probably be unprofitable.

The 23 samples from Red Mountain between the Spaulding and Fossil mines show considerable uniformity in composition and in the results of concentration. This fact tends to emphasize the conclusions that can be based on the tests. The samples averaged 37.3 per cent Fe, 23.6 per cent SiO_2, and 8.9 per cent CaO; that is, their iron content is about the same as the average of the workable upper bench ores, but their silica content is 10 per cent higher and their lime content is more than 7 per cent lower. The concentrates obtained from these samples contain 0.4 per cent more iron and 2 per cent less silica than the brown ores, and, in addition, have a lime content of 8.1 per cent. Thus concentration yields a product of greater value than the brown ores. These results are the more encouraging because they were obtained with an iron recovery of 94.1 per cent and a concentration of 4 tons of crude ore into 3 tons of final product.

Three samples of ore from the Irondale seam were tested, samples 35 and 36 from the Ruffner mine, and sample 37 from the Hammond mine. The average iron and silica contents of these ores, 38 per cent Fe and 22.1 per cent SiO_2, is about the same as those of the lower bench Big seam ores. The concentrates average 45.1 per cent Fe and 14.2 per cent SiO_2, a little higher in silica than the Big seam lower bench concentrates, but still as good as the brown ores. In addition the concentrates doubtless have an appreciable lime content that would increase their value. On the whole, then, the ores tested from the Irondale seam have about the same composition as the Big seam lower bench ores from the producing part of the district, and are approximately as amenable to concentration.

Two samples of Ida seam ore were tested, one being hard ore and the other soft. Sample 37 from the Ruffner mine represents a poor hard ore, carrying 28.2 per cent Fe and 40.8 per cent SiO_2. The slimes from the test are so low grade that mixing them with the concentrates appreciably lowers the grade of the product; discarding them reduces the iron recovery to only 77.8 per cent, but the concentrate contains 47.5 per cent Fe and 14.7 per cent SiO_2, and is as low in silica as the average brown ore, with 2.5 per cent more iron. These results indicate that the ore has undergone partial alteration and is to be classed as semihard. The soft ore, sample 39 from the Hammond mine, is too poor to market in the crude state, but its concentrate had the same silica content as the brown ores and 10 per cent more iron.

With but few exceptions, then, and these being the unusually low-grade material, the experiments in concentrating the siliceous red

ores have yielded final products that would have a value in excess of that possessed by the brown ores of the district.

The experiments above are based on crushing the ore to pass 20 mesh, probably as fine as would be practical. In order to determine, however, the degree to which the grade of the concentrate could be raised by still finer crushing, in five tests part of the ore was crushed to pass 35 mesh, and the concentrate resulting from the separation of both sizes was determined. For purposes of comparison the results are tabulated below.

Results of finer crushing.

Sample.	20-mesh test.					35-mesh test.					Slimes.	
	Concentrates.	Slimes.	Tailings.	Iron.	Silica.	Concentrates.	Slimes.	Tailings.	Iron.	Silica.	Iron.	Silica.
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
6	61.0	10.9	28.1	42.5	20.6	41.0	19.8	39.2	43.7	16.7	34.5	13.0
14	63.3	9.2	27.5	45.1	13.5	52.7	21.4	25.9	45.3	13.0	44.3	14.9
20	60.4	9.4	30.2	42.3	16.1	47.6	21.0	31.4	42.1	13.3	39.8	12.4
27	68.2	10.0	21.8	43.5	13.2	55.8	21.1	23.1	45.7	11.0	44.0	12.8
29	71.5	11.3	17.2	48.0	12.1	58.4	22.5	19.1	48.1	11.7	43.8	16.6
Average	64.9	10.2	25.0	44.3	15.1	51.1	21.2	27.7	45.0	13.1	......	......

These results show a very small average increase in iron in the finer concentrates and a 2 per cent decrease in silica. The amount of the tailings increased only a little, the change being almost entirely in the amount of the slimes at the expense of the concentrates. In the table the first and last slime analyses are of the 35-mesh slimes and the other three of the 20-mesh slimes. Thus increased sliming lowers the average grade of the slimes. If the slimes and concentrates are mixed to form a final product with as high iron recovery as for the similar product from the 20-mesh crushing, the grade of it will be but little if any higher and there will be no increase in grade of the final product to compensate for the finer crushing. Hence, 20-mesh crushing is fine enough to produce an adequate freeing of the constituent ore particles to yield an efficient separation.

In the above summary, except where otherwise indicated, the final product of concentration is considered to be the combined concentrate and slimes. The average composition of all the concentrates is 46.4 per cent Fe and 13.4 per cent SiO_2, and that of all the slimes is 44.7 per cent Fe and 13.5 per cent SiO_2. Of the total iron in the crude ore, that in the concentrates averages 80.6 per cent and that in the slimes 13.1 per cent. The average quantity of concentrates is 63.3 per cent, and that of slimes is 10.6 per cent. Consequently, if the slimes are added to the concentrates, the average composition of the final product will be 46.2 per cent Fe and 13.4 per cent SiO_2; in other words, this procedure does not change the silica content

and lowers the iron content only 0.2 per cent, out the average iron recovery is raised 13.1 per cent, or from 80.6 per cent to 93.7 per cent. The advantages of mixing these two products in raising the iron recovery and eliminating the need of slime treatment are obvious.

That crushing alone brings about a concentration of the iron in the finer sizes and a concentration of the silica in the coarser sizes is strikingly shown, the slimes (less than 200 mesh) from the crude ore being of practically the same composition as the concentrates from the sizes coarser than 200 mesh. In order to show this tendency in more detail the concentrates and tailings of each mesh size of five samples were analyzed, and from these analyses the composition of the crude ore of each of these sizes was calculated. The results are tabulated below.

Increase of iron in the slimes.

	Sample 3.		Sample 8.		Sample 10.		Sample 19.		Sample 39.		Average.	
	Fe.	SiO_2.	Fe.	SiO_2.	Fe.	SiO_2.	Fe.	SiO_2.	Fe.	SiO_2.	Fe.	SiO_2.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Crude ore	32.4	29.3	35.9	27.0	35.7	15.0	38.4	20.2	39.5	19.3	36.4	22.2
20 to 28	28.8	40.1	29.4	38.5	32.5	20.5	32.1	32.3	31.9	29.9	30.9	32.3
28 to 35	29.6	33.1	32.2	33.0	36.1	15.9	36.6	23.8	35.2	24.4	33.9	26.0
35 to 48	31.8	24.7	36.1	24.0	37.1	14.0	37.4	19.7	37.3	19.9	35.9	20.5
48 to 65	32.5	20.1	39.5	19.3	35.0	12.4	38.6	16.0	38.3	17.3	36.8	17.0
65 to 100	33.9	18.3	40.9	18.7	35.3	12.2	39.9	14.8	38.7	16.2	37.7	16.0
100 to 150	36.3	16.7	43.5	16.4	38.4	10.9	42.3	13.2	43.0	15.2	40.7	14.5
150 to 200	43.3	12.7	45.1	16.0	42.3	9.7	44.7	13.3	45.3	14.6	44.1	13.3
200	39.8	12.7	46.1	14.0	40.0	8.9	45.5	11.3	47.4	11.7	43.8	11.7
Concentrate	42.3	16.1	45.5	11.9	46.2	7.9	45.3	12.0	45.3	11.8	44.9	11.9

This table shows that the two coarsest sizes, 20 to 28 mesh and 28 to 35 mesh, are of lower grade than the crude ore, whereas the finer sizes are of increasingly higher grade.

PRACTICAL VALUE OF THE EXPERIMENTS.

The bearing of the results of these experiments on probable results of concentration on a commercial scale by wet methods or with magnetic separation will now be considered. The author knows that the method of concentration he used is not feasible on a commercial scale, and its efficiency of separation is not obtainable in a commercial plant. The experiments were made to determine the degree to which the silica might be separated from the iron—that is, granted a perfect separation of the mineral particles, what is the result?

If this result indicates that concentration is feasible, the devising of a commercial method of separation would be encouraged. If, on the other hand, a perfect separation of the mineral particles does not yield a marketable product of sufficient value, there is no use working at separation on a commercial scale. The results obtained in the

experiments have demonstrated that, so far as the experiments go, a solution of the problem is possible.

Results obtained in the application of the Moxham-du Pont haloid process to the concentration of low-grade iron ores open the possibility of the commercial application of the method used in this investigation and may render the results of these experiments directly applicable. But while this process is in the experimental stage, it will be better to consider the bearing of these results on separation by ordinary wet methods or by magnetic methods.

Wet methods of separation are based essentially on the differences in specific gravity of the mineral components of an ore. In the author's experiments the ores were crushed to pass 20 mesh, a fineness that is not at all unusual in ore mills. As the iron oxide in the ore tested is much softer than the silica that is to be removed, crushing causes an increase of iron in the finer sizes. So marked is this concentration of the iron that the crude material passing through 200 mesh has practically the same iron content as that obtained by concentrating the material coarser than 200 mesh. This fact is of great importance as it eliminates the slime problem in the use of wet methods. The material finer than 200 mesh may be separated by washing immediately after crushing, allowed to settle, and then added to the concentrate obtained from the rest of the material. The concentrates obtained with the same ratio of concentration will not be of as high grade as those made in the experiments because of less complete separation, but this difficulty could be met by increasing the ratio of concentration a little, thus raising the grade of the concentrate and lowering the iron recovery. As the concentrates from the tests of lower bench ores of the Big seam, for example, represented an iron recovery of 94.1 per cent, it is evident that a little lowering of the iron recovery to meet the decreased efficiency of commercial work would still permit a good recovery and give a concentrate of high enough grade. Hence there seems to be no reason to doubt the possibility of obtaining equally good concentrates, although with a lower iron recovery, on a commercial scale by wet methods.

Equally favorable conclusions can be drawn in regard to the results that may reasonably be expected from applying magnetic separation to remove the more magnetic particles of the crushed ore, as in an ore similar to that under discussion the more magnetic particles are those high in iron and low in silica. In other words, the magnetic susceptibility is determined by the same factors as the specific gravity and is a linear function of the latter. Consequently, crushing frees the ore particles for magnetic separation to exactly the same degree as for specific gravity separation. Therefore a perfect magnetic separation should yield results identical with those obtained by a

perfect specific gravity separation. But in ordinary practice a perfect magnetic separation is no more obtainable than a perfect gravity separation. In either case the grade of the final product can be maintained by increasing the ratio of concentration a little at the expense of the iron recovery. As stated above, in the author's concentration experiments iron recovery was so high that a small decrease in it would not be prohibitive.

The experiments have, consequently, demonstrated the possibility of producing from ores now valueless and being permanently lost by present mining methods a marketable product. Also, it is probable that as good results can be obtained commercially by any of the usual methods of ore treatment if the decrease of efficiency is compensated by increasing the ratio of concentration.

COMMERCIAL ASPECTS OF THE PROBLEM.

As the tests indicate that concentrates of higher grade than the best of the ores now available in the Birmingham district can be obtained from the siliceous ores of the district, the question remains whether concentration would be profitable. The answer requires the determination of two things—first, the cost of crushing, concentrating, and nodulizing the concentrates; second, the value of the concentrates as compared with the crude ore. The author does not have the necessary data and does not consider himself competent to supply such figures, for they should be based on experience with concentration on a large scale and on familiarity with mining costs and the price of ore in the district. However, some general suggestions are offered.

Beneficiation of low-grade iron ores is widely practiced; it includes magnetic separation and nodulizing of low-grade magnetites. Magnetic concentration of the siliceous red hematites would involve higher treatment cost than for magnetites because, generally speaking, finer crushing would be needed. On the other hand, these ores can be mined cheaper than many magnetites thus treated. Gravity methods of wet concentration for low-grade iron ores have been successfully used on a large scale in the Lake Superior region, and have made available great quantities of ore that are too low in grade to be shipped crude. Hence it is reasonable to presume that the costs of treatment would not necessarily be prohibitive.

The margin allowable for treatment costs can be determined more nearly. During the years 1910 to 1915 the red ores and the brown ores of the district showed the following range in prices, according to the United States Geological Survey:[a]

[a] Figures for 1910 and 1911 from Mineral Resources of the United States for 1911, Part 1, p. 130. Figures for 1912 and 1913 from Mineral Resources of the United States for 1913, Part I, p. 305. Figures for 1914 and 1915 are from Mineral Resources of the United States for 1915, Part 1, p. 291.

Prices of red and brown ores of Birmingham district.

	1910	1911	1912	1913	1914	1915	Average.
Red ores	$1.19	$1.17	$1.16	$1.18	$1.21	$1.25	$1.19
Brown ores	1.53	1.47	1.43	1.61	1.49	1.68	1.54

During these six years the average price of the brown ores was 35 cents in excess of that of the red ores. It has been seen that the value of the concentrates would exceed that of the brown ores, and the cost of mining the lower bench ores in mines working the upper bench ought to be less than the present cost of mining the upper bench alone. Therefore, the margin allowable for treatment should be in excess of 35 cents. How much larger it might be can be determined by those having complete data on mining costs and the value of the ores as determined by chemical composition.

That one must guard against assuming too low a cost for mining lower bench as compared with upper bench ores is pointed out by Burchard, who says:[a]

To recover the lower ore at present would, however, introduce serious complications in mining. At the Tennessee company's mines the slopes are cut in the lower bench of the seam about 8 feet below the working level of the headings, so that tramcars of ore may be dumped over the tipple into the skip in the slope. If the lower bench of ore were mined also, the slopes would have to be depressed 8 feet below the bottom of this bench in order to accommodate skip haulage. This would necessitate maintaining for some distance a slope height of 25 to 28 feet, which would be excessive and would involve deepening and retimbering the present slopes. Beyond the present faces the slopes might be driven below the parting, leaving the upper bench above the slope. The matter of setting props to support the roof in the workings where 18 to 20 feet of ore are taken out would also prove inconvenient.

In slopes where tram haulage is employed the problem is simpler, since it is not necessary to depress the slope below the bottom of the ore that is being mined. Part of the ore from the lower bench can be obtained in either case by cutting the floors of the rooms lower. By this method, however, the floors become too flat to permit the ore to be shot down to the cars, and the expense of moving it is thereby increased.

Evidently the problem is discouraging in view of present costs and conditions, but if for every ton of ore mined from the lower bench nearly a ton of ore in the upper bench might be saved for future use, it would seem worth while to carry the investigation as far as possible, even to the extent of equipping one slope to mine the whole seam on a scale that would enable the relative costs to be compared on a working basis.

In spite of such difficulties there certainly ought to be a margin in favor of the lower bench ore. As those ores are not utilized at

[a] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Ala.: U. S. Geol. Survey Bull. 400, 1910, pp. 124, 125.

present and are being destroyed as reserves, and as the mines are now equipped for mining the upper bench ore, none of the charges now assumed by the upper bench ore should be distributed between it and the cost of producing the lower bench ore. The cost of mining both ores should be determined, and then from that cost should be subtracted the present cost of mining the upper bench ore. The difference is all that should fairly be charged against the lower bench costs and would certainly be less than the present figures for the upper bench ores. The difference would be applicable to meeting concentration charges. Moreover, a decidedly important consideration would be the doubling of the ore reserves.

From this consideration of the factors involved, it seems reasonable to assume that the margin allowable for meeting concentration charges is considerably more than 35 cents.

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